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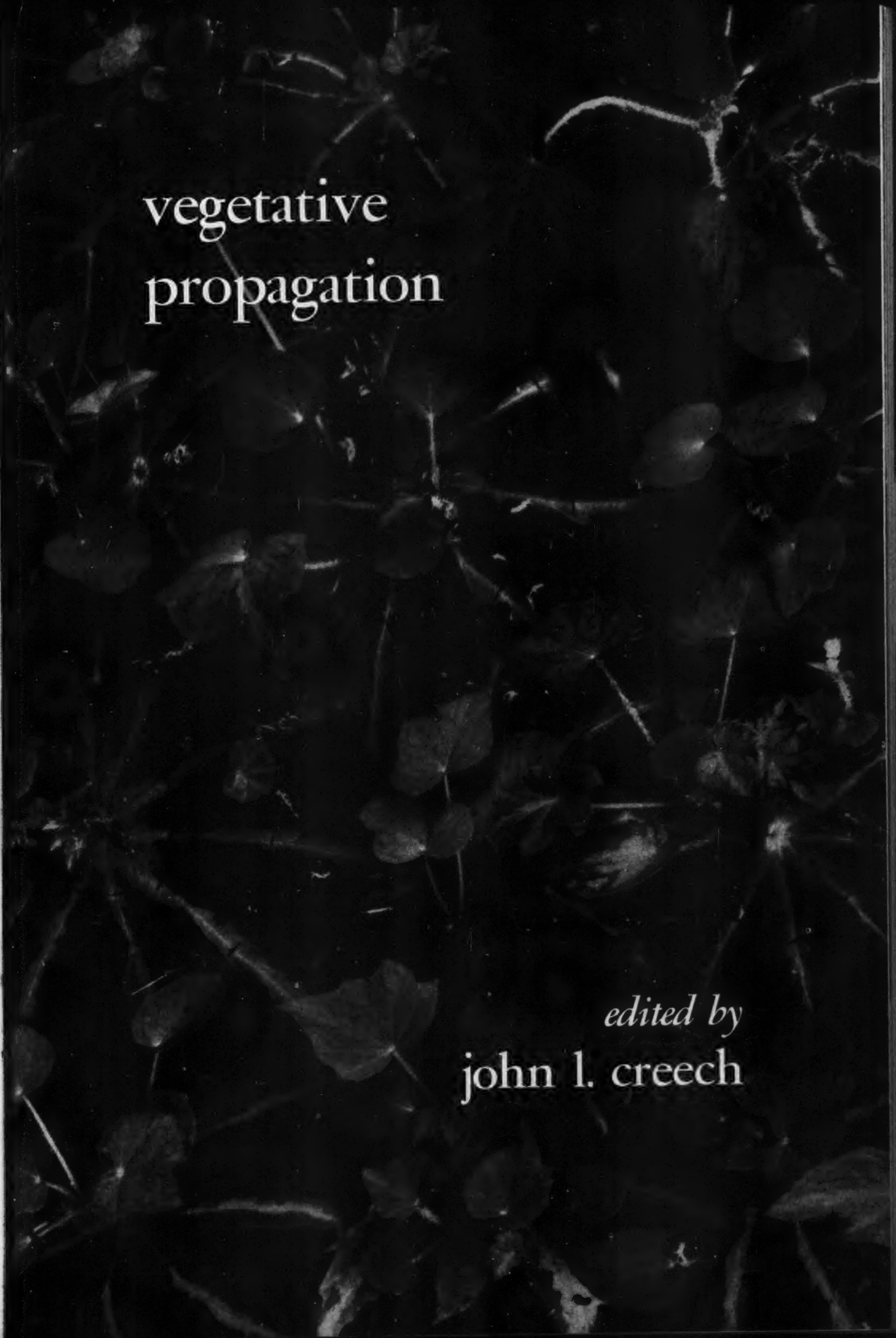
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Introduction

Probably the beginnings of the practices we now speak of as plant propagation are earlier than recorded history. One finds bits of such plant lore in the earlier tales of more than one civilization and a gradually evolving mass of data that contained a strange mixture of folk-wisdom and fantasy. Bit by bit, the fantastic was pruned away leaving the sound core of knowledge gained by experience until the best men, trained almost by apprenticeship, came to be expert in the practices that lead to success, for the most part with only a partial knowledge of the reasons that made their successes possible.

It is only within relatively recent times that scientists, often trained in sciences not immediately related to horticulture, have turned their attention to that field with amazing results, some of them of immediate value, some of them steps to knowledge still undiscovered.

In the papers brought together here, largely in response to the interest expressed by our membership in answer to a questionnaire sent out in 1952, there will be found, not a complete manual on plant propagation, even of the sections devoted to vegetative propagating, but papers that should be of interest and value to the amateur and home gardener, as an insight into scientific investigations as well as papers of more immediate usefulness.

Slowly in the hands of more and more investigators, the plant, a living thing, will yield up all the secrets of its structure, its growth, its life cycles, until any one will know what portion to take, at what time, under what conditions, and the various conditions under which to maintain the chosen portion, until it can function once more as a living entity, identical with the plant from which it was taken.

For the amateur or non-professional who has developed past the initial stages of gardening, a trial of all the methods of plant propagation and the production of plants for himself, becomes an ever-growing wonder.

B. Y. M.

The Rooting Of Leafy Stem Cuttings

William E. Snyder[1]

The continued growth and health of a plant is dependent upon the correlation of many internal processes. These processes may be markedly affected by conditions within the plant and of the environment in which the plant is growing. Some of these processes may be localized more or less entirely in a given part of the plant, while other processes may occur in many or all parts of the plant. The study of these processes is known as plant physiology and the study of the structures of the plant as plant anatomy. It is now recognized that plant propagation depends for its success upon special aspects of plant physiology and plant anatomy. To understand satisfactorily just what occurs during the initiation of roots or buds on a cutting, during the union of the stock and scion of a graft, or during the germination of a seed, it is necessary to resort to a consideration of these internal processes and the structures which are involved.

In many plants, such as coleus, chrysanthemum, rose, privet, forsythia, and yew, a new root system develops on stem cuttings quite readily. The time required may vary from as little as ten to twelve days for coleus to three months or more for yew. In many plants, such as pine, apple, peach, and spruce, it is impossible at the present time to obtain rooting of a sufficient number of cuttings to make this method of propagation economically feasible.

Our knowledge of the factors involved in the rooting of cuttings has been obtained largely from practical experience and from research to determine the conditions which are necessary for the rooting of so-called "easily-rooted" plants. To a lesser extent information has been obtained from studies of plants considered to be "difficult" to root.

Seed-bearing plants consist of three vegetative parts: root, stem, and leaf. Each of these contributes to the growth of the entire plant. The roots serve to anchor the plant in the medium, to absorb water and the essential minerals, and, in some cases, to store large quantities of reserve food materials. The leaf functions in the exchange of gases (both carbon dioxide and oxygen), as the chief area of photosynthesis (carbohydrate manufacture), and of transpiration (evaporation of water), and in some instances for the synthesis of auxin (a plant hormone), vitamin B_1, and other organic materials. The stem is the connecting link between the roots and leaves through which water and minerals are translocated from the roots to the leaves and the growing points and through which carbohydrates and other elaborated organic materials may be translocated to the roots. The stem may also possess chlorophyll and stomata, and, to a lesser extent than the leaves, photosynthesis, transpiration, and the exchange of gases may occur. At the tip of each stem and root are growing points, where, during the growing season, the formation and enlargement of new cells result in the continued growth of stem and root.

When the stem tip is cut off, as in making a terminal cutting, some or all

[1]Associate Professor of Ornamental Horticulture, Cornell University, Ithaca, New York.

of these numerous internal processes are altered or interrupted. Water and minerals which normally were absorbed through the roots must now be taken into the plant primarily through the cut surface of the stem. Measurements of water absorption made by the writer have shown that much less water is absorbed through the cut surface than had been taken in by the roots. If transpiration from the leaves continues unabated, wilting occurs. There is a reduction in the exchange of gases, photosynthesis, and other processes of the leaf when the plant is in a wilted condition. Part of the materials which are normally translocated to the roots may be leached from the stem but it has been found that there is a build-up in the quantity of many materials in the stem above the cut. From these illustrations, it can readily be appreciated that the stem cutting differs in many respects from the complete plant and the cutting must be handled in special ways until the new root system is established.

It is proposed to discuss the origin and development of roots on leafy stem cuttings first, and then to consider the various conditions of the cutting itself which affect the development of these roots.

Origin Of The Root

Regardless of whether a root develops from a stem, a leaf, or from another root, it develops inside the parent structure. Such internal origin is said to be endogenous. Figure 1 shows the tissues found in a young, herbaceous chrysanthemum stem, in the region where the basal cut would be made. An examination of this illustration shows four major areas: 1) an extensive pith in the center of the stem, 2) a ring of vascular bundles surrounding the pith, 3) a narrow cortex on the outside of the vascular bundles, and 4) a single layer of cells covering the stem, known as the epidermis. The vascular bundles consist of xylem (wood) on the inside and of phloem on the outside. The function of these tissues is the translocation of water, minerals, and elaborated foods within the plant.

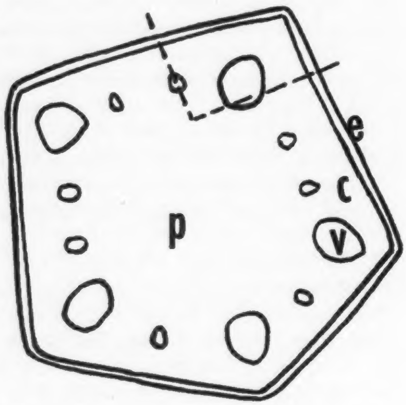

Figure 1. Schematic diagram of the cross-section of a chrysanthemum stem made about five inches below the growing point. Marked segment at top shown enlarged in Figure 2. (e:epidermis, c:cortex, v:vascular bundle, p:pith).

Between the vascular bundles, and immediately to the outside of them, are thin-walled cells. These cells have not become specialized and, under certain conditions, readily become meristematic (capable of dividing to form new cells). Certain cells of the phloem also are capable of becoming meristematic.

When the basal cut is made, many of the cells are injured. Within a short time, however, the cut surface becomes

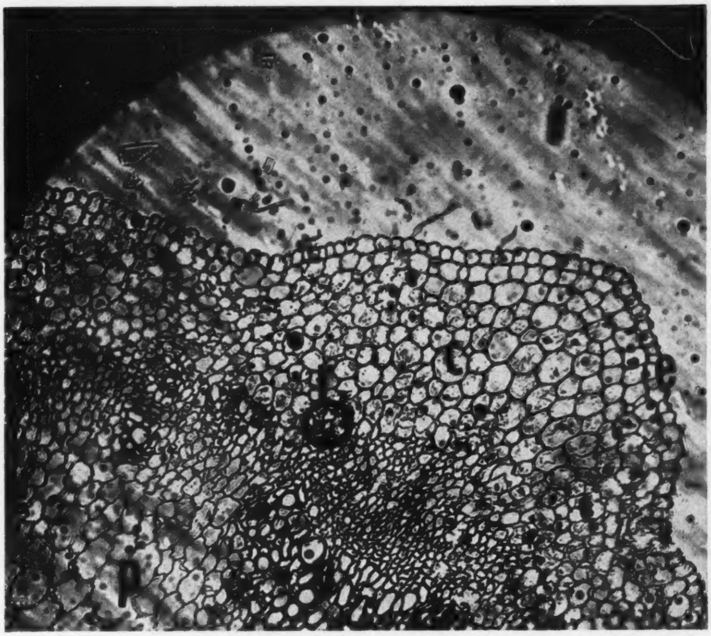

Figure 2. Photomicrograph of a chrysanthemum stem section showing a root initial. Area shown is approximately equivalent to the designated segment of Figure 1. Enlarged 200 times. (e:epidermis, c:cortex, v:vascular bundle, p:pith, r:root initial). From Stangler (37).

covered with a layer of suberin (corky cells) which is developed by the uninjured cells adjacent to the cut surface. Groups of cells between the vascular bundles or immediately external to the vascular bundle begin to divide, forming many new cells of small size. The resulting cells continue to divide (Figures 2 and 3) and gradually this group of newly formed cells take on the orientation and appearance of a root tip. The vascular tissue (xylem and phloem) of the new root and of the stem become connected. The first root primordia usually arise within one or two millimeters of the cut surface. Subsequently new roots arise higher on the stem.

In many plants, for example, coleus and chrysanthemum, the root continues to grow outward through the cortex and epidermis and emerges from the cutting at a right angle to the stem. In the carnation, *Dianthus caryophyllus,* there is a band of thick-walled cells, called fibers, external to the point of origin of the root (37). The root grows outward to these fibers but cannot grow through them. As a consequence, the root grows downward and emerges through the base. Basal emergence of the roots on stem cuttings of the com-

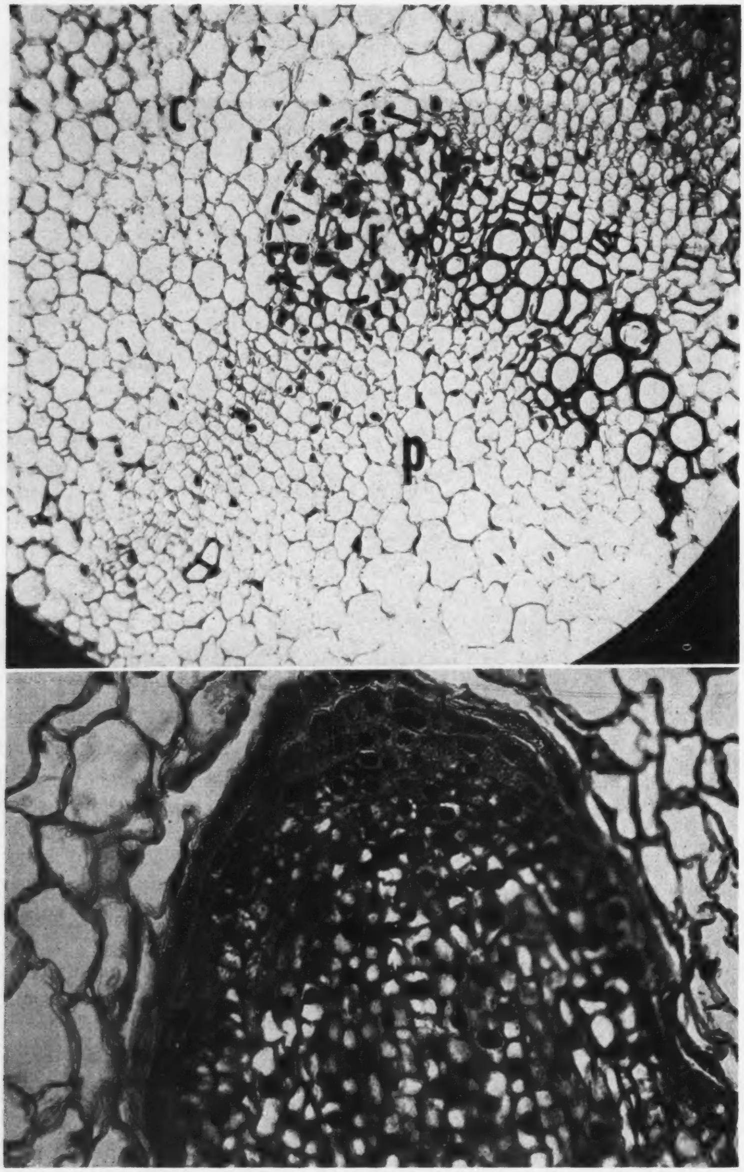

Figure 3. Top: Enlarged section of the chrysanthemum stem showing the root initial on the side of the vascular bundle, approximate area of initial is encircled. Enlarged 400 times. (c:cortex, v:vascular bundle, p:pith, r:root initial). From Stangler (37).

Bottom: A root primordium growing through the cortex of the chrysanthemum stem and about to emerge through the epidermis. Enlarged 400 times. From Stangler (37).

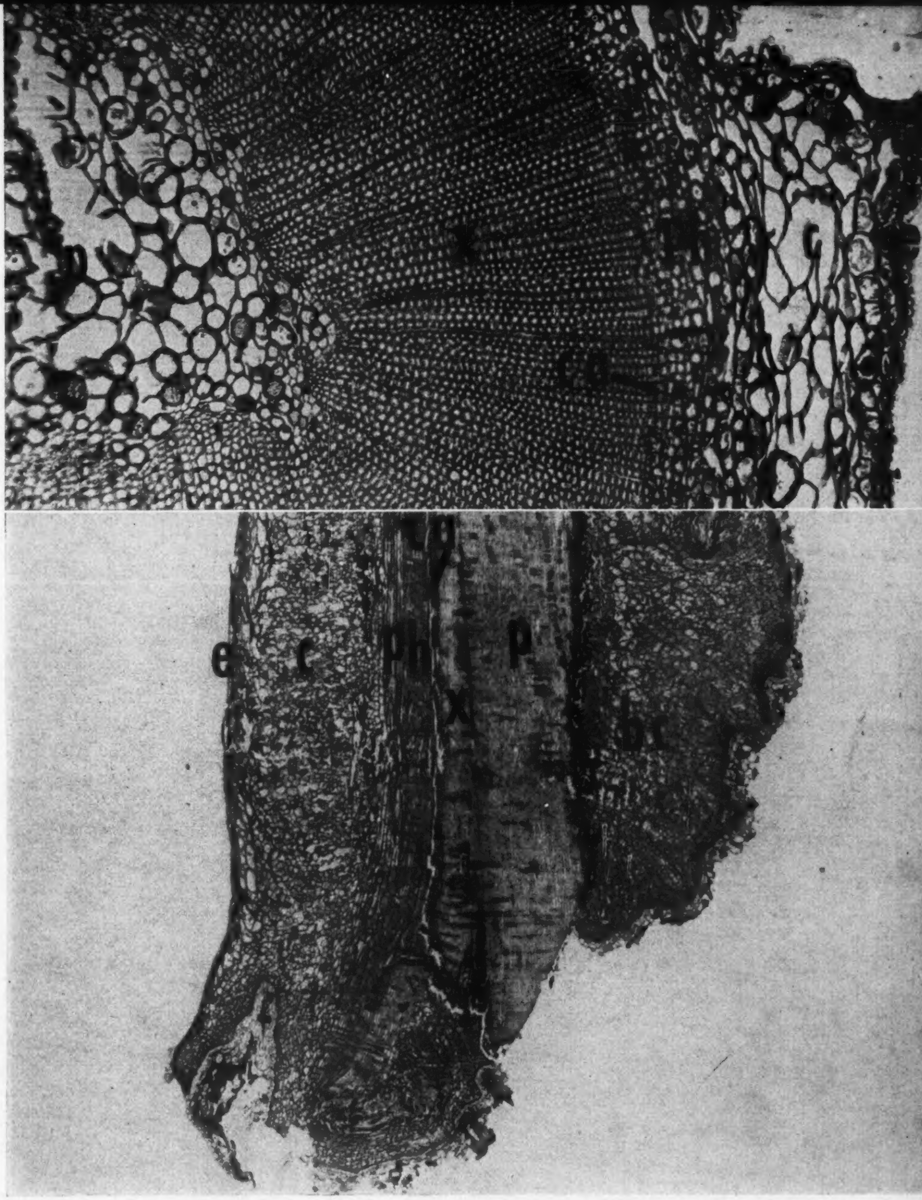

Figure 4. Top: Cross-section of a one-year old stem of Japanese yew made about eight inches below the stem tip. Enlarged 100 times. (e:epidermis, c:cortex, ph:phloem, ca:cambium, x:xylem, p:pith). From Hiller (23). Bottom: Longitudinal section of a one-year old stem of Japanese yew made 70 days after the cuttings was placed in the rooting medium. Abundant callus has arisen from the cambium and phloem. Enlarged 25 times. (e:epidermis, c:cortex, ph:phloem, ca:cambium, x:xylem, p:pith, bc:basal callus). From Hiller (23).

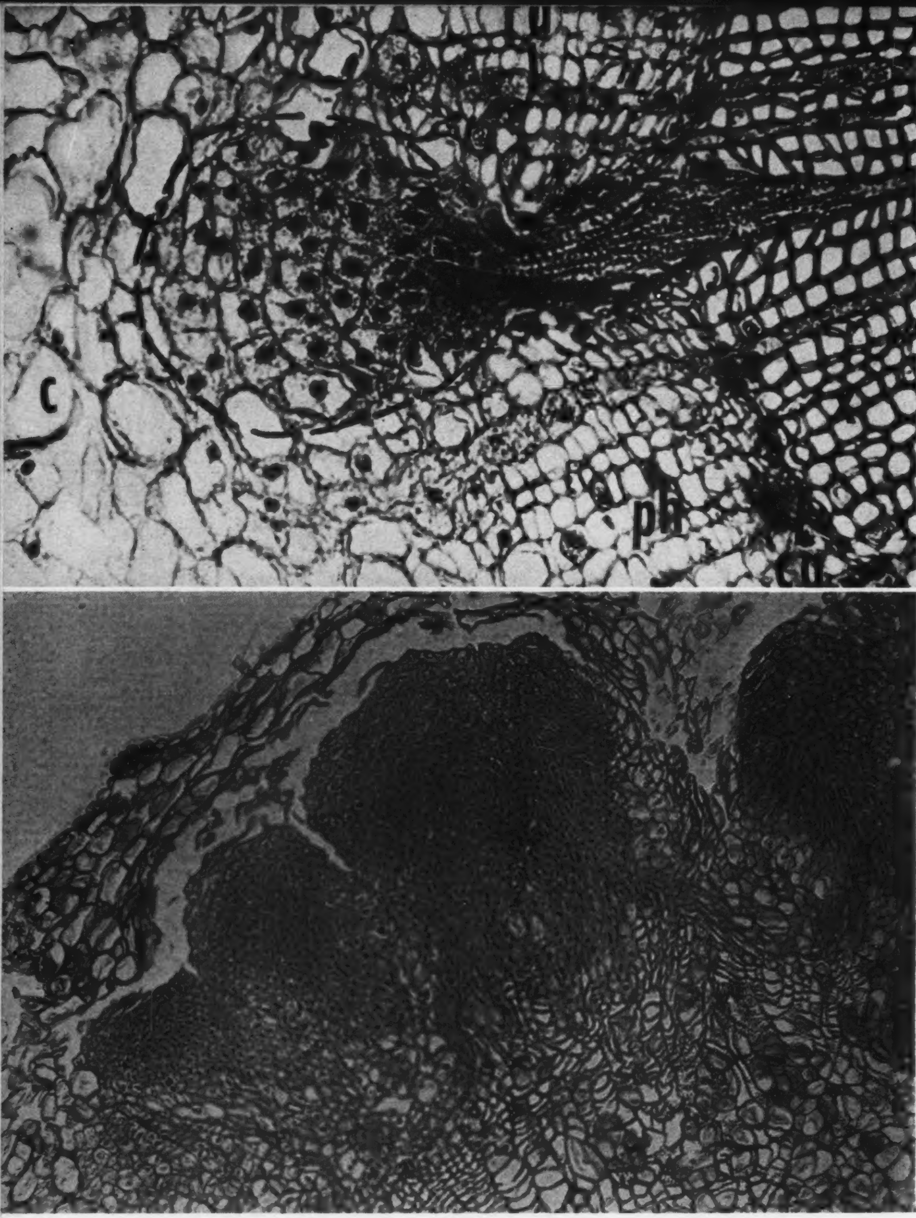

Figure 5. Top: Cross-section of a Japanese yew cutting showing a root primordium, approximate area encircled, in the area of the phloem and in association with a ray. Enlarged 300 times. (c:cortex, ph:phloem, ca:cambium, x:xylem, ra:vascular ray, r:root primordium). From Hiller (23).
Bottom: Cross-section, near the base of a Japanese yew cutting, showing several root primordia about to break through the epidermis. Enlarged 100 times. From Hiller (23).

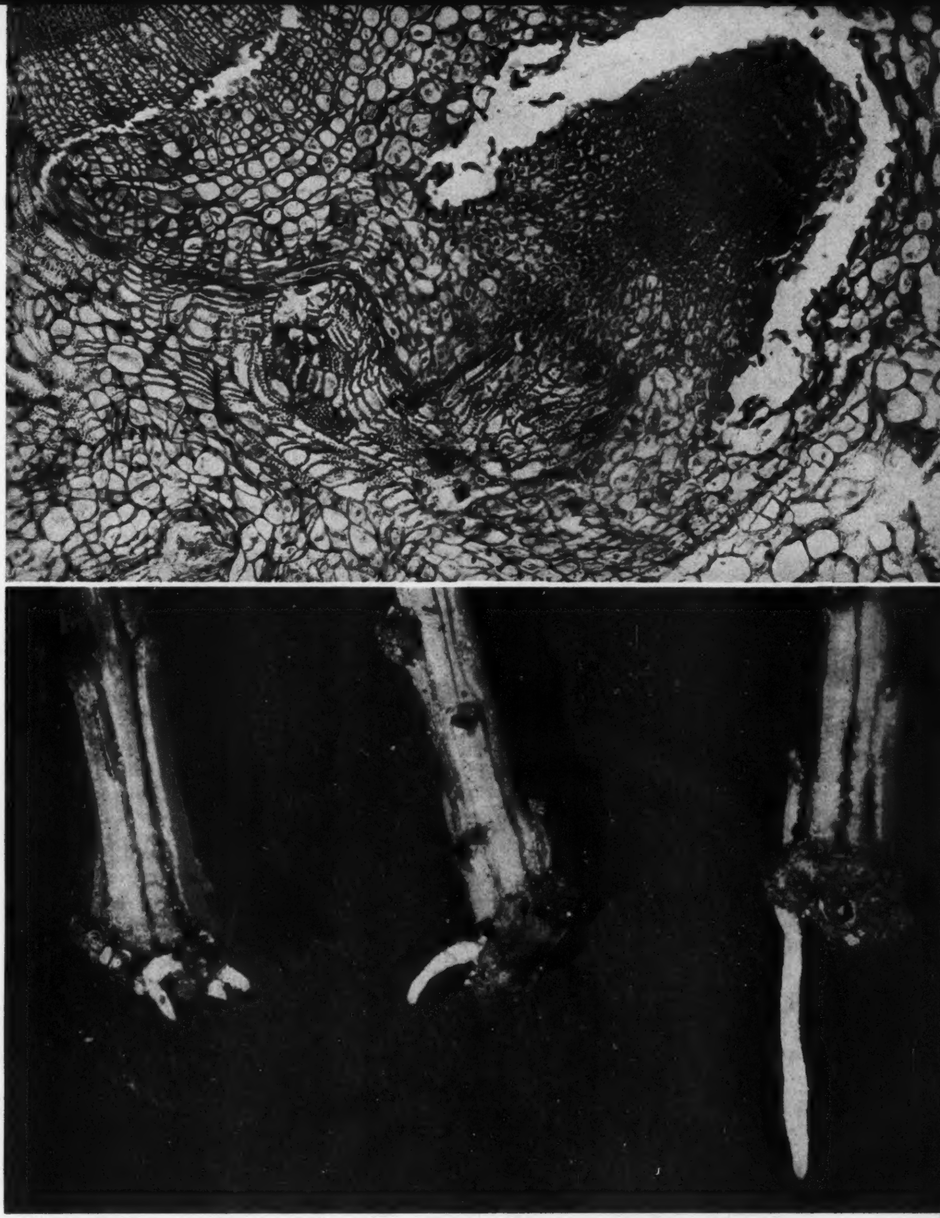

Figure 6. Top: Cross-section of a Japanese yew cutting taken above the basal cut and showing a well developed root primordium growing through the cortex. Enlarged 100 times. From Hiller (23). Bottom: Japanese yew cutting showing basal callus and young roots which developed in the stem tissue near the base. From Hiller (23).

mon purslane, *Portulaca oleracea,* has been reported (9), but there are no fibers present in this stem which mechanically prevent the continued outward growth of the root. Why the root did not grow outward through the cortex was not ascertained.

The general appearance of the tissues of a very young stem of a woody plant is comparable to those described for the herbaceous stem. In the young stem of woody plants, however, and frequently in herbaceous stems late in the growing season, a band of cells located between the xylem and phloem starts to divide. This band of cells is known as the cambium. The cambium bands of adjacent vascular bundles gradually extend laterally and become connected. Thus there is developed a continuous band of cambium around the entire stem. Some of the cells formed by the cambium differentiate into phloem but most of the new cells become xylem. The addition of xylem and phloem by the cambium results in the increased growth in diameter of woody stems. In young tissue of many woody plants the cambium becomes active early in the growing season and even in June and July, when gardeners or nurserymen collect softwood cuttings, there may have been some growth in diameter.

The sequence of events in the origin of roots on stem cuttings of several woody plants has been studied. Some of these plants are the rose (6, 37), forsythia (40), raspberry (39), pine (13), arbor-vitae (2), and Japanese yew (23). Figures 4, 5, and 6 show the initiation of roots on cuttings of the Japanese yew.

Within a few days after the cutting is made, the cut surface becomes suberized as described for the herbaceous stem. A short time later a callus usually forms on the base of the cutting. It is formed primarily by division of the cells of the cambium and adjacent phloem, however, cells of the pericycle, cortex, and pith may also contribute to the formation of the basal callus. Callusing usually precedes rooting and, while it is not essential for successful rooting, the appearance of the callus gives a feeling of assurance to the propagator that rooting will occur. While the callus is being formed, root initials may also be developing in the stem tissue immediately above the basal cut. In most woody plants the roots develop from the phloem tissue which in turn has developed from the cambium. The first initials usually arise within a few millimeters of the basal cut, but subsequently roots develop higher on the stem. In some instances a cambium develops within the callus tissue and root initials may develop from cells derived from this cambium. Only rarely do roots arise directly from the callus on the base of the stem cutting.

In a few woody plants, root initials are developed on the stem while it is a part of the parent plant. These initials develop partially, then become dormant, and, as the stem increases in diameter, become imbedded in the stem tissue. Such dormant root initials have been termed "preformed root initials" and "root germs" (45). If the stem is made into cuttings, these preformed root initials resume growth. Preformed root initials have been reported in willow (45), some *Ribes* (45), and certain cotoneasters (8). Most woody plants which have been studied do not possess them.

From these brief remarks, it is evident that the basal cut becomes covered with a protective layer of suberin and in some cases a callus develops.

The origin of roots on stem cuttings of both herbaceous and woody plants follows a similar pattern. The roots arise internally from groups of cells near the vascular tissue of the stem. As the root grows through the stem, the vascular tissue formed in the root and that of the stem becomes connected. A successful cutting is one which regenerates a root system and establishes a fully functioning plant.

Physiology Of The Cutting Wood

Since propagation by cuttings is basically a problem of growth and differentiation, it would be expected that the controlling factors in rooting are those which have been shown to influence these processes. These controlling factors can be divided into two categories: first, internal factors within the plant, and, second, external or environmental factors. Although the effects of many of these factors on the rooting of cuttings is known, what actually causes a group of cells to divide and then to form a root initial is not known. Why certain cells are stimulated to form a root initial but adjacent and apparently similar cells are not so stimulated likewise remains undetermined.

Closely related plants frequently differ markedly in rooting capacity. Zimmerman and Hitchcock (51) have reported a variation of forty to eighty per cent in the rooting of cuttings from four different plants of the American holly, *Ilex opaca.* A marked difference in the rooting of the red Chinese hibiscus, *Hibiscus rosa-sinensis* and a white form, 'Ruth Wilcox,' has been reported by van Overbeek and coworkers (21, 46, 47). As will be discussed later, the failure of the white form to root is apparently associated with the failure of the leaves to supply nutrient materials necessary for rooting. Stem cuttings of the single forms of *Gypsophila paniculata,* 'Baby's Breath,' can be rooted with considerable success, but most growers consider the double variety, 'Bristol Fairy,' to be extremely difficult to root. During recent years, the rooting of stem cuttings of many rhododendrons has resulted from the use of growth regulators and humidification, but satisfactory results have not been obtained with other varieties. In general, the white - flowered rhododendrons are more easily rooted than the red-flowered forms.

With many woody plants, cuttings made from seedlings are easy to root, whereas cuttings made from older plants are difficult to root. Frequently the seedling or young plant is different in appearance from a mature plant, but in many species there is no obvious visible difference. Differences in leaf shape in English ivy, apple, and junipers, and possession of thorns in citrus have been noted between young and mature plants. The term "juvenility" has been used to designate the immature condition. This subject was recently reviewed by O'Rourke (28).

The horticultural literature includes reports of many plants in which cuttings from juvenile plants can be rooted with relative ease but cuttings from mature plants seldom initiate roots. Thimann and Delisle (43) have reported success in rooting cuttings of the white pine, *Pinus strobus,* taken from plants one-half to three years old, but no success with cuttings from plants ten to sixty-five years old. Juvenile growth of the English ivy, *Hedera helix,* bears lobed leaves and does not produce flowers and fruits. In contrast, mature plants bear entire leaves and develop flowers and fruits. Root-

ing of ninety to one hundred per cent of the cuttings taken from English ivy possessing juvenile foliage is common, but in the experience of the writer cuttings made from stems with mature foliage are difficult to root. Other plants possessing juvenile conditions which have been rooted with good success include apple, pear, apricot, peach, citrus, olive, papaya, lychee, mango, firs, spruces, and many species of pine.

Juvenility is probably genetically determined. Apparently in some species, factors which promote vigorous growth may hasten the onset of maturity, however, in others, this is not the case. In my opinion, other processes, such as flowering and fruiting, may also be affected by juvenility. The cause of juvenility, as well as why cuttings made of juvenile wood root quite readily, are unknown at the present time.

Relative position of the wood on the parent plant. Whether the cutting material is made from the upper or lower half of the parent stem, and from lateral or terminal branches may have a marked effect on the ability of cuttings to root. In an experiment with cuttings of red maple, *Acer rubrum,* a higher percentage made from stems of the lower half of the crown rooted than those made from the upper half (17). Similar results have been obtained with blueberry (27), Norway spruce (18), white pine (16), and other species. Cuttings made from lateral branches of some plants tend to grow flat or prostrate rather than upright (spruce and Araucaria). Calma and Richey (5) reported that better rooting and more vigorous plants were produced from grape cuttings made from the middle and basal region of a stem. These authors also reported that the middle and basal part of the stem possessed more carbohydrates and less nitrogen than stem tips. As will be discussed later, conditions of high carbohydrate-low nitrogen favor rooting. Since the use of root-promoting chemicals does not negate the effect of position of the wood, the natural distribution of auxin in the plant probably is not primarily responsible.

Maturity of the tissue. Probably one of the most important considerations of the rooting of stem cuttings is the condition of the tissue at the base of the cutting. Even with such easily rooted plants as coleus, chrysanthemum, privet, and forsythia, the maturity of the tissue is important. If the tissue is soft and immature, the cuttings are more susceptible to rot, and, if the tissue is old and hard, a considerably longer period of time may be necessary to obtain a satisfactory rooting.

The most satisfactory condition of the tissue lies somewhere between these two extremes for most plants. Many woody plants make an initial growth during the early part of the growing season. It is frequently stated that the "best" time to take a stem cutting is immediately after this period of growth. As with most of the factors under consideration, maturity of the tissue is of considerably more importance for those plants which are difficult to propagate by stem cuttings.

Many practical plant propagators have learned by years of experience the "best" time to take the cuttings of particular plants. This is frequently expressed as a definite time during the year. In actuality, it is not the time of the year, but the condition of the tissue that is important. The practical propagator has learned to associate these conditions with specific times, but instead of following an iron-clad rule in this respect, he has learned to vary the time depending upon the growing

conditions for the particular season. In reality then, the "time" serves as a guide to indicate about when the tissue should be in the best condition.

Cuttings of the Japanese yew, *Taxus cuspidata,* are usually made during the fall or winter, carried in a greenhouse, and are well rooted and ready for outside planting in the late spring. In the experience of the writer, yew cuttings can be successfully rooted, and in high percentages, during any month of the year merely by varying the environmental conditions of the cuttings while in the rooting medium. Softwood cuttings of lilac can be successfully rooted if taken during and preceding the period of flowering. Experiences at Cornell University have shown that if lilac softwood cuttings are maintained under conditions of a saturated atmosphere, cuttings of many varieties can be successfully rooted if taken as late as mid-July.

Differences in rooting of cuttings taken at different times of the year have been reported for many plants, for example, *Camellia japonica* (3) and *Ilex opaca* (51).

Many propagators have contended that cuttings made with a heel or a mallet of two-year wood root better than if no two-year wood is present on the base of the cutting. Hitchcock and Zimmerman (24) compared the rooting response of four kinds of softwood cuttings made from shoots of the same age. The four types were: 1) with a mallet of two-year wood, 2) with a heel of two-year wood, 3) with the cut at the base of the current season's growth, and, 4) with the cut one-fourth to three-fourths inch above the base of the current season's growth. As would be expected, some species rooted better if the base of the cutting possessed two-year wood; others better if no two-year wood was present; and, still others rooted equally well regardless of whether the base of the cutting possessed two-year wood or not. Wyman (50) studied the effect of a heel of two-year wood on the rooting of several narrow-leaved evergreens. He reported that the presence of older wood at the base of the cutting was of no significance for the species tested with the exception that the heel possibly reduced the rooting of the giant arborvitae, *Thuja plicata.*

Many commercial growers contend that better rooting is obtained for cuttings of *Buxus sempervirens* if a heel of older wood is present; however, other growers believe the heel either is unnecessary or retards rooting.

Position of the basal cut with reference to the node. The effect of the position of the basal cut with reference to a node (the portion of the stem where a leaf arises) has been studied by numerous investigators. Probably the most extensive investigation of the influence of the position of the basal cut was made by Chadwick (7). Of the eighty-six species tested, five rooted best if the cut was made one-half inch above the node; seventeen rooted best if the cut was made at the node; and, forty-one rooted best if the cut was made one-half inch below the node. The place of cut was immaterial for the remaining twenty-three species.

Grape and clematis have a natural capacity to form roots at the nodes, but if the cuttings are treated with a root-promoting substance, rooting occurs along the internodes as well (52). The California privet, *Ligustrum ovalifolium,* was one of the plants listed by Chadwick (7) as rooting best if the cut was made one-half inch above the node. It is the experience of the author that softwood cuttings of the California

privet root equally well regardless of the position of the cut providing the cuttings are treated with a root-promoting material. It would seem that at least with some plants, if the naturally occurring growth regulator is a limiting factor, better rooting may be obtained if the basal cut is made at a specific place with reference to the node; but if ample auxin is available, the position of the basal cut may be immaterial. For other plants the influence of the position of the basal cut may be related to differences in the tissue arrangement between nodal and internodal areas of the stem.

Effects of wounding at the base of the cutting. It has been noted in many, but not all cases that a wound made at the base of the cutting frequently improves the rooting response. The wound has been made in several ways varying from slitting the bark on one or both sides of the base of the cutting to removing a slice of the bark as deep as the cambium for one-half to one inch on one or both sides of the base. In many instances, the rooting occurs along the margin of the wound. Beneficial results have been recorded for many species including the red-leaved Japanese barberry, *Chamaecyparis lawsonia alumii, Eurya japonica, Ilex opaca,* and others (42). Beneficial effects include an increased number of cuttings rooting, decreased time required for rooting, more roots per cutting, and the formation of a better type of root system.

One worker (12) has reported that there is an increase in water absorption by wounded cuttings. It is well established that there is an accumulation of growth regulator and consequently a mobilization of carbohydrates and other plant products at the region of a wound. No comprehensive study has been made of the reasons why wounding may be beneficial, however, nor of a survey of the application of wounding to the propagation by stem cuttings.

Role of organic and inorganic nutritive conditions. In the formation and growth of roots on stem cuttings, energy, as well as materials, are required. Numerous investigators have studied the effect of the availability and kind of carbohydrates and the inorganic nutrients, especially nitrogen, on the rooting of stem cuttings. The work of Starring on tomato and Tradescantia (38), Schrader (33) and Reid (30, 31, 32) on tomato, Smith (34) on coleus, and Pearse (29) on grape, have shown that the quantity of available carbohydrate and nitrogen markedly affects the rooting of cuttings.

The findings of these workers indicate that rooting is negligible on stem cuttings lacking an available supply of either nitrogen or carbohydrates. If there is an abundant supply of nitrogen, and carbohydrates are low, growth of shoots is favored but rooting is slight. An abundant supply of carbohydrates favors rooting, either with or without an abundant supply of nitrogen. Excess nitrogen usually results in a reduction of the number and length of roots formed, even when accompanied by an abundant supply of carbohydrates.

Smith (34) found that coleus cuttings rooted much better if the carbohydrate occurred as starch rather than as soluble sugars. Zimmerman and Hitchcock (51) have reported that cuttings of the Japanese holly, *Ilex crenata,* kept in the dark, lost starch regularly for six weeks and did not root. Comparable sets of cuttings, kept in the light, increased the quantity of starch present and rooting was excel-

lent. More recently, Haun and Cornell (22) have reported that the level of nitrogen in the stock plant significantly influenced the number of cuttings which rooted, whereas the quantity of potassium or of phosphorus had little effect. Moderate to low quantities of available nitrogen increased rooting. Although with a high level of nitrogen in the plant, fewer cuttings rooted, and there were more and longer roots on those cuttings which rooted than on rooted cuttings from stock plants possessing less available nitrogen.

On the basis of these reports it would seem that cuttings from plants making a moderate growth—in which carbohydrate accumulation is in excess of the accumulation of inorganic nitrogen—should result in better rooting.

Role of growth regulators (hormones). Prior to 1935, investigations of the use of chemicals to stimulate the rooting of cuttings included such materials as acetic acid, potassium permanganate, hydrogen peroxide, sugars, and various inorganic nitrogen compounds. The results obtained with these chemicals were inconsistent and certainly not spectacular. Following the publication in 1935 of works by Cooper (10) and by Zimmerman and Wilcoxon (53) on the effects of indoleacetic acid (IAA) and related chemicals on the initiation of roots of cuttings, thousands of papers have been published on the chemical stimulation of rooting of cuttings. A majority of these papers is concerned with the responses of hundreds of different ornamental plants to the kinds and concentrations of root-promoting chemicals. Several excellent tabulations of these findings have been made: Avery and Johnson (1), Mitchell and Marth (26), and Thimann and Behnke (42). The use of root-promoting chemicals has become commercial procedure in the propagation of many plants by stem cuttings. Several commercial preparations are available in which indolebutyric acid, naphthaleneacetic acid, naphthaleneacetamide, and other materials are disbursed in talc. There are several hundred known organic chemicals which may elucidate some or all of the plant responses known to be effected by the naturally occurring hormone, indoleacetic acid.

Important benefits which might be expected following the use of a root-promoting chemical on stem cuttings are: 1) increase in the number of cuttings developing roots, 2) increase in the number of roots developed per cutting, 3) decrease in the time required for rooting to occur, and, 4) improved quality of the root system produced. The use of these growth promoting substances, however, is by no means a "cure-all." It soon became apparent that the use of growth regulators will not replace good cultural practices, that many plants do not respond to these chemicals, and that harmful effects may be noted if too strong a concentration is used.

It is now known that the plant hormone, auxin, can be found in most parts of the plant. At the present time, the evidence indicates that most of the auxin in the plant, if not all, is in the form of indoleacetic acid. Auxin is produced primarily in the apical bud or buds and to a lesser extent in young, expanding leaves. One characteristic of the naturally occurring auxin is that the transport is polar, that is, from top of the plant toward the base. In the stem it moves through living tissue in the phloem. If the stem is girdled (removal of a strip of bark around the stem and inward to the cambium) the downward movement is stopped and auxin accumulates above the girdle

This increased concentration results in a swelling of the stem, caused by the formation of many new cells, and the initiation of roots. Likewise the downward movement of auxin is retarded when a cutting is made and it accumulates in the stem tissue above the cut. If the base of a leafy cutting is treated with a root-promoting material in solution, some of the material enters the xylem (wood) and is carried upward in the transpiration stream.

Why and how these growth regulators stimulate cell division is not known. It has been shown that the application of a growth substance brings about numerous changes in the activities of the cells. Following treatment of the base of the cutting, the rate of respiration is increased, there is a mobilization of carbohydrates to the area, and changes occur in the form of carbohydrates and organic nitrogen compounds present in the tissue. It appears that the growth substances accelerate the rate and intensity of the changes of normal metabolism of the cutting.

Anatomical examination of cuttings shows that the rate and number of root initials formed is increased following application of a growth substance, but that the developmental stages are identical with those of cuttings not treated (23).

In many difficult-to-root cuttings which respond favorably to treatment, it is logical to assume that the concentration of the naturally occurring auxin is below the optimum level for rooting and that treatment with a growth substance raises the level, resulting in increased rooting. On the other hand, with difficult-to-root forms which respond poorly or not at all to treatment, it must be assumed that even though the optimum concentration of growth substance may be obtained, rooting is limited by one or more other conditions.

Laboratory experiments have shown that under certain conditions application of thiamine or of pyridoxine may result in an increase in the growth of roots; however, under most conditions, and certainly under field conditions, the use of these materials is of no significance. Went, Bonner, and Warner (49) have shown that stem cuttings of pea and lemon treated with indoleacetic acid and thiamine produced more and longer roots than stem cuttings treated with indoleacetic acid alone. Microscopic examination of the pea cuttings treated only with the indoleacetic acid showed the presence of innumerable root primordia which had failed to continue growth and emerge from the cutting. It was concluded that thiamine does not stimulate the initiation of root primordia but does increase the growth of roots and the number of roots which emerge from the cutting. Thiamine has been reported beneficial to some cuttings but to have no effect on the root growth of others. It is quite possible that there is insufficient thiamine in the cuttings of the former group to bring about the maximum response, but that there is adequate thiamine naturally occurring in the latter group. Additional thiamine, of course, would be of no benefit.

Not all growth regulators promote growth. One organic chemical, 2,3,5-triiodobenzoic acid, is quite similar chemically to certain of the synthetic root-promoting materials but is actually anti-auxinic in its action. In other words, this chemical prevents the responses commonly brought about by auxin. Whereas auxin inhibits bud growth and stimulates root initiation, 2,3,5-triiodobenzoic acid may stimulate

bud growth and inhibit root initiation. Coleus cuttings treated with a very weak solution of 2,3,5-triiodobenzoic acid (one part per million) prevented rooting of coleus cuttings for over seventy days, but untreated cuttings were well rooted within two weeks (35). It would seem quite possible that some plants might produce chemical materials which prevent rooting—that is, root inhibiting substances. To date, however, none has been identified.

The results of some experimental work have been interpreted as inidicating the presence of a specific root-inducing hormone. Went (48) believes this material is produced by the leaves and has termed it "rhizocauline." The evidence is inconclusive, however, and a final decision must await direct proof of its existence and the determination of the role played in the initiation of roots.

Treatments of cuttings with growth substances plus nutrients and of growth substances plus fungicides have been reported as giving better results than the use of growth substances alone (14, 15, 19, 20, 25, 29, 36, 41). Such beneficial effects are readily accounted for if it is assumed that both auxin and nutrients necessary for root initiation are limited in the cutting.

Role of buds. Early investigators, such as Van der Lek (45), have recorded that if buds are removed from the cuttings, root initiation is definitely inhibited, as well as the formation of basal callus. Some evidence is also available that strongly sprouting buds or actively growing shoots may be beneficial in the rooting of cuttings of certain plants. Since the discovery of the role of indoleacetic acid in the rooting of cuttings and the knowledge that buds are the primary source of auxin in the plant, this influence of buds on the rooting of cuttings is understandable. Although there is some auxin distributed throughout the stem, a continuous supply is necessary since auxin is used up or destroyed during growth. If buds are present on a cutting, there is a continuous supply of auxin available, but if the buds are removed, growth of callus and root initiation is limited by the quantity of auxin available in the tissue of the stem.

Function of the leaf. There are two main reasons for reducing the leaf area of softwood stem cuttings: 1) to reduce the loss of water, and, 2) to conserve space in the propagation bench. Many propagators make a practice of removing the entire leaves from the lower half of the cutting, trimming off the tip half of the remaining leaves. More recently it has been advocated that only the basal leaves which would be in the rooting medium, and such other entire leaves as necessary to conserve space, should be removed. The trimming of the leaf tips is not recommended. Reduction in water loss from the cutting is accomplished by shading from bright sunlight, various systems of humidification, and, in some instances, by maintaining a constant water level in the bottom of the bench.

Even with such easily rooted plants, as coleus, privet, forsythia, and chrysanthemum, it has been shown that reductions in the leaf area result in a reduction of rooting quantity. Since the leaves are the primary photosynthetic part of the plant and since it has been shown that rooting is enhanced by a high level of available carbohydrates, it would be expected that, within limits, the rooting response is proportional to the leaf area. Nevertheless, there is considerable evidence that the leaves have additional effects on the rooting

of cuttings. Calma and Richey (4) have shown that a fifty per cent reduction of leaf area, by removing half of each leaf, results in a greater reduction in rooting than by removing fifty per cent of the leaf area by removing one-half of the entire leaves. Injury and other harmful effects of trimming were suggested as inihibiting the rooting of the cuttings. For instance, if the leaves are removed from all but one side of a cutting, rooting occurs primarily on the side with the leaves.

Both leafy and leafless cuttings of *Derris elliptica* and *Lonchocarpus utilis,* two members of the pea family, root if the cuttings are treated with either indolebutyric acid or naphthaleneacetic acid (11). The roots developing on the leafless cuttings, however, did not grow well and soon died. This indicates that products of the leaves are necessary for growth of the roots.

The function of the leaf in the production of carbohydrates has been recognized and emphasized for many years. It was established only in comparatively recent years, however, that the other activities of the leaf are of primary importance. The leaf is the receptive organ for the length of day stimulus of flowering (photoperiodism) and the organ of synthesis for thiamine, pyridoxine, and other organic materials essential for growth.

A recent investigation of the function of leaves on rooting for hibiscus has been reported by van Overbeek and co-workers (21, 46, 47). A leafy cutting of the red hibiscus is easy to root, but the closely related white variety, 'Ruth Wilcox,' is difficult to root. Two distinct factors are necessary for the rooting of both forms. One of these factors is auxin, while the other is produced by the leaf. Experiments demonstrated that the leaf factor is produced in darkness as well as in light. The white form is difficult to root because: 1) there is a deficiency of auxin, 2) the effectiveness of the leaves of the white variety in producing the factor(s) is lower than in the leaves of the red form, and 3) the leaves drop off soon after the cutting is made.

Auxin-treated, leafless hardwood cuttings either of the red or the white hibiscus do not root, however, if a scion of the red hibiscus with leaves is grafted onto the white cutting, rooting occurs with relative ease. It was concluded that the leaves of the red hibiscus produced some factor or factors essential for the rooting of both forms. A further series of tests showed that if leafless cuttings of the red hibiscus were treated with a root-promoting chemical (indolebutyric acid), a sugar (sucrose), and a nitrogen compound (ammonium sulfate or arginine were best), the number of roots produced equalled those produced by cuttings possessing leaves. The quality of the roots produced by the chemically treated, leafless cuttings was inferior to those produced by the leafy cuttings. Thus, it would seem that the primary function of the leaves in the rooting of the red hibiscus is to supply the cuttings with nutritive factors, which, experimentally at least, could be replaced by sugar and nitrogen.

It must be concluded, there is abundant evidence that one of the main functions of the leaf in the rooting of softwood cuttings is to supply various nutritive materials. There is also some evidence that the leaf may have other functions in the initiation and subsequent growth of roots on cuttings. Additional investigations are certainly necessary before the complete significance is fully understood.

Many of the conditions of the stock

plant or of the cutting itself which affect the ability of the cutting to produce roots have been discussed. Some of these factors may markedly affect the rooting of all cuttings; others are of primary importance for the difficult-to-root forms. Since the rooting of cuttings is the result of many activities within the plant, any one or more of these several conditions may be responsible for the failure of cuttings to root. Difficult-to-root species can be stimulated to root in some instances by wounding the base of the cutting or by supplying synthetic growth regulators or nutrients to the cuttings. In many other instances, however, the exact cause or causes of the failure to root have not been determined.

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Figure 7. Rhododendron decorum—a. Current season's shoot, showing portions of leaf-and-bud to be cut. b. Completed leaf-bud cutting. c. Rooted leaf-bud cutting, showing developed bud. d. Shoot developed.

Leaf-and-Bud Cuttings

Henry T. Skinner [1]

There is a well known ability of certain plants to be reproduced by leaf cuttings. Such cuttings may be made of portions of the leaf blade, as with varieties of *Begonia rex;* of the whole leaf, or the leaf margins, as in bryophyllum; or of the leaf with leafstalk attached, as with our household friend, the African-violet. These are all true leaf cuttings which are capable of producing roots and of developing adventitious or formerly non-existent shoot buds from merestematic tissues located usually in the general region of root formation.

Cuttings consisting of leaf and leafstalk can actually be rooted with a great many different kinds of plants, especially among the evergreens, whose leaves can be retained in healthy condition until rooting occurs. Why, then, does one not hear more of this type of propagation as a practical method for many rather than a few plants? The answer lies in the fact that while leaf cuttings of many begonia species, peperomia, etc., produce roots, shoots, and new functioning plants with relative ease, the majority of our garden plants do not. They may produce abundant roots which afford us great encouragement but they may seldom form the necessary shoot to produce a new plant. The cutting will merely linger for some weeks or months and then eventually die. Simple leaf cuttings of Sheffleria or camellia or leaf fascicles of white pine will root with comparative ease but will go no further. Except in rare cases, no shoot buds develop and the cuttings sooner or later die. Only occasionally is a vegetative bud produced by the newly dividing cells near the point of root regeneration.

To circumvent this difficulty the cutting must be more than a leaf alone.

[1] Director, United States National Arboretum, Washington, D. C.

It must include such tissues as already carry a dormant shoot bud or are capable of producing this bud. These tissues or these buds naturally occur at the leaf-axil as a part of the plant stem and with this knowledge one can now make a new type of leaf cutting which

TAYLOR

Figure 8. Rooted leaf-bud cutting of dahlia showing new shoot growth.

includes not only the leaf blade and petiole but also a small attached portion of the plant stem with its dormant bud or buds. This has been called a "leaf-bud" cutting. It is actually a reduced shoot cutting rather than a true leaf cutting. If it can produce roots, it now also has the potentials for vegetative growth and the production of a new plant.

The care and handling of leaf-bud cuttings is little different from that of the ordinary shoot cutting. Well developed leaves may be severed from current season's shoot growth with a sharp knife, slicing off each leaf so as to retain a half or three-quarter inch portion of the stem attached to the leaf-stalk and bearing the axillary bud. (Figure 7, a and b). The stem portion may be treated with a hormone powder before shallow burying in a suitable rooting medium. If conditions are good, new roots should form within a few weeks. In potting the newly rooted cutting, the bud should be kept at the soil surface. With many plants, the new shoot will develop quite quickly; with some of the hardy plants, it may remain dormant over winter to break with the first warm weather in spring. Subsequent culture is the same as for any young specimen of the variety involved.

With this kind of procedure a wide range of plants is reported to have been successfully propagated by leaf-bud cuttings, including semi-woody herbaceous types, such as chrysanthemum and Pelargonium; tropical shrubs, such as Bougainvillea, Cocculus, Codiaeum, hibiscus, Ipomoea, and Thunbergia; hardy deciduous plants, such as blackberry, Japanese maple, privet, and elm; and numerous hardy evergreens, including citrus camellia, Osmanthus, Ilex, the evergreen privets, Leucothoe, Pieris, and rhododendron. (Figure 7, c and d).

Limitations of the method lie essentially in the ease and speed with which rooting can occur before deterioration of the leaf in the rooting medium and in the ability of the axillary bud to make a satisfactory start in producing the new plant. Leaf-bud cuttings of many deciduous plants are not success-

ful because the thin textured leaves cannot maintain themselves long enough for rooting to occur, particularly as the season becomes advanced. Cuttings from these plants should be taken early, as soon as the leaves are fully mature and the wood has begun to harden. Even with the evergreens, earliness may be a real factor in success, for a mature, though not too hardened leaf, may root more readily, while the axillary bud may also be more inclined to break promptly to produce a sizable young plant before going into winter dormancy. If winter approaches before top growth is secured, however, it will be well to give the potted cuttings a normally cool winter environment to insure growth the spring following.

While in some instances it seems that leaf-bud cuttings may root more easily than stem cuttings taken from the same plant, this may not always be true. Results will inevitably vary with the particular plants from which cuttings are secured. *Rhododendron ponticum* may produce fine young stock quite quickly from leaf-bud cuttings; another species or variety may root, but be too slow to produce top growth, while a third may fail to root entirely.

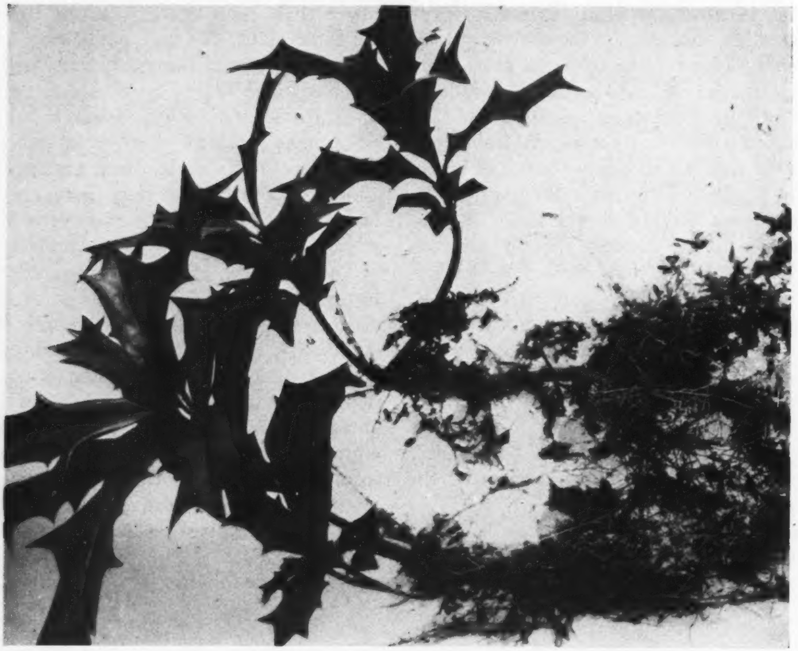
This is a form of cutting propagation to try out with problem plants or especially with those where the supply of suitable cutting wood is very limited. If used as leaf-bud cuttings, it is evident that the several leaves from a shoot of Ilex or camellia may provide eight to ten young plants for growing into size, as against the single somewhat larger specimen that might otherwise result from use of the shoot itself as a cutting.

Root Cuttings

John L. Creech [1]

Rooted cuttings can be made from the roots of some species that are difficult to propagate from stem cuttings. This method is quite frequently applied to woody legumes and to a lesser extent to other plant groups. According to Priestley and Swingle (6), root cuttings tend to produce adventitious shoots more readily than adventitious roots; just as stem cuttings are prone to regenerate roots. It seems in both cases as if each were trying to replace that part of the plant which was missing. The adventive shoots formed on root cuttings are more likely to be found at the upper (proximal) end of the cuttings than at the lower (distal). (Figure 9). Thus, the most successful root cuttings will be those obtained as close as possible to the base of the plant. This proximity to the base of the parent plant might also be expressed in terms of the diameter of the root cuttings. Kvarazkhelia (5) reported in a study of the vegetative propagation of the tea plant that when

[1]Horticulturist and Superintendent, United States Plant Introduction Garden, Glenn Dale, Maryland.



CREECH

Figure 9. Root cuttings of Ilex cornuta showing roots formed mainly at distal end of cutting and shoots at proximal end.

he separated the root cuttings into thick (over 2 cm.), medium (1 cm.), and thin (less than 1 cm.) pieces, the thick cuttings gave the best results and the thin ones the poorest, namely, 52 to 73 per cent, 37 to 45 per cent, and 9.5 to 18 per cent, respectively. This has also been observed at the Glenn Dale Plant Introduction Garden with *Cyrilla racemiflora* when root cuttings were separated into two groups, one-half inch or over and less than one-half inch. In addition to a higher percentage of rooting, the thick cuttings also produced more vigorous shoots than did the small roots (Figure 10).

As a supplement to increasing the number of plants derived from root cuttings, it may be desirable to use some of the newly developed shoots as softwood cuttings. This may seem a roundabout means of obtaining softwood cuttings but results show that these cuttings will often root better than similar cuttings taken from stem pieces. Toole (7) took softwood cuttings of *Albizzia julibrissin* both from root pieces and stem pieces. Those shoots originating from roots, rooted 100% in twenty days while the ones obtained from stems failed completely, although both lots were treated identically.

Root cuttings should be made either

CREECH

Figure 10. Root cuttings of Cyrilla racemiflora showing less root development and inferior shoot growth on smaller section of root cutting (left) than from larger section (right).

in the fall or during the winter months. Hoblyn and Palmer (3) reported that root cuttings of plum rooted much better when planted in December through February than if set in April. In the propagation of the beach plum, *Prunus maritima,* Graves (2) used roots of lead-pencil size collected in the fall. These were cut into lengths of three to four inches and buried outdoors at a depth of two to three inches with the cuttings laid horizontally. By this

method, a fifty per cent stand of plants may be obtained.

Roots can also be dug from around the parent plant and propagated in the greenhouse. The roots are cut into three to four inch lengths and placed in a flat of moist sphagnum moss. Cuttings may be laid horizontally or placed on end with the thicker (proximal) end uppermost and covered with an inch of moss. One text suggests that by reversing this latter position, better results will be obtained. In view of the relatively greater adventive shoot development at the upper end, there is little basis, theoretical or experimental, for this suggestion. Cuttings will produce new shoots and roots promptly and may be transplanted after three or four months, but in some instances, shoots will appear and immediately wilt due to the failure of adventive root formation. This lagging of root development is perhaps the main cause for failure of root cuttings to succeed.

Plants in the following genera have been described as developing successfully from root cuttings: Albizzia, Chaenomeles, Clethra, Cyrilla, Daphne, Ilex, Koelreuteria, Lagerstroemia, Maackia, Prunus, rhododendron (azalea), Syringa, wisteria and Xanthoceras. Only one report concerning the propagation of conifers by root cuttings was noted in my study. Jelinek (4) observed that Araucaria roots would regenerate new plants when cut into pieces four to five inches long and placed, several together, in a pot leaving the upper ends exposed. No indication of percentage was noted.

A further observation concerning root cuttings was that reported by Bateson (1). He noted that with some variegated plants, such as the *Pelargonium zonale,* root cuttings will not reproduce the foliage variegation but will give only green plants. The same situation exists in some Bouvardias in which solid-colored flowers have appeared on plants grown from root cuttings although the parent plants had been bicolored, that is, the variety 'Bridesmaid' was described as having pinkish-white, double flowers but plants propagated by root cuttings produced only scarlet double flowers. This variety may be considered as a periclinal chimera, having a skin or cortex of pinkish-white over a core of scarlet. Since the adventitious buds on the roots arise from the core (endogenously) they are solely of that tissue and in this case resulted only in scarlet flowers.

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Budding And Grafting

W. E. Whitehouse[1]

In the majority of cultivated species, seedling variability makes it impossible to perpetuate desirable traits, except in a few instances. The natural distribution of sex, aproximately 50-50, does not suit the purpose for which dioecious plants are grown. Asexual propagation has thus been resorted to in order to preserve seedlings or vegetative variations which are preeminent in one quality or another. When vegetative propagation is necessary and layerage or cuttage yield poor results, budding and grafting have been practiced.

Some plants are grafted with ease, others with difficulty, and some not at all. There are various explanations for this variability, but in this discussion we are more concerned with the techniques successfully worked out. Much the same is true of compatibility or congeniality in grafting, which has been found to be of varying degree, and about which much has been written.

The nurseryman, after years of experience, has become highly versed in the propagation methods most suitable for each plant type. The less experienced grower, while equally interested in the propagation of plants, lacks this opportunity. This discussion of budding and grafting is in no sense intended as a complete coverage of the subject;[2] however, it does aim to focus attention on propagation techniques that are in common usage.

Writers usually introduce the subject of budding and grafting with a definition of terms so that their readers may become immediately familiar with what each represents:

Stock has reference to the root, tree, or portion of the tree, into which the bud or scion is set. In most cases it is grown from seed.

Scion denotes the twig of the desired variety which is grafted on the stock.

Bud refers to a simple lateral leaf bud of the variety which is budded on the stock.

Cambium layer refers to a certain layer of living cells surrounding all woody portions of the tree. During growth, these cells divide to form new cells; those produced on the inside of the layer forming wood, and those on the outside, the inner bark. The cambium layer is thus the source of all growth in thickness of the wood, stem, and of most of the callus formation, particularly in the older wood. In the apple, for example, the cambium has been shown to be from six to ten cells only in thickness. While the exact limits of this zone of growth are not discernible with the naked eye, it is readily located, for peeling the bark from the tree while the bark is slipping splits the cambium layer, part adhering to the bark and part to the wood. The paste like substance that can be scraped from the wood surface exposed by lifting the bark is composed in part of cambium-like cells.

Top-working means the grafting over of a tree on the trunk or in the

[1]Senior Horticulturist, Division of Plant Exploration and Introduction, Plant Industry Station, Beltsville, Maryland.

[2]For more complete information on budding and grafting, the reader is referred to the *California Agricultural Extension Circular No. 96*, "Propagation of Fruit Plants" by C. J. Hanson and E. R. Eggers and *Special Bulletin No. 142*, "Grafting in the Apple Orchard" by H. A. Cardinell and F. C. Bradford, sources which the writer consulted freely in assembling this article.

branches as distinguished from grafting or budding near the ground or in the roots.

Scion wood is selected from the previous season's growth. This can be distinguished from the older wood by starting at the tip and proceeding backward to the first ring of scars encircling the twig. Older wood has spurs instead of the simple buds that characterize the young wood. Twigs that have made a growth of from one to two feet in the last season and are of lead pencil thickness furnish the best wood.

Union between stock and scion is effected through the formation of callus by both stock and scion. When these meet, they fuse—the whole process being no more than a wound healing. Union proceeds more rapidly if the wounded areas are protected against drying out. In most forms of grafting rapid union is essential to maintenance of life in the scion. It has been pointed out that union between stock and scion may be obtained from approximation of the cambium edges of stock and of scion, as in the so-called cleft and whip grafts; through union of a cambium edge with a cambium surface, as in the bark graft, the bridge graft, and some forms of approach graft; or through placing the inner surface of the bark of the scion against the surface of the woody cylinder of the stocks, as in "budding with the wood removed." A very slight variation in technique may change the manner of establishing unions; thus one bud may be set with the "wood in" and the next with the "wood out," changing the tissue union, but not the practical results.

The condition of the budstick and rootstock at the time the work is performed, plays an important role in the success of the work. Under greenhouse conditions, mature buds of cherry, mango, citrus and avocado, for example, are much more apt to unite and start growth when worked on their respective rootstocks if both have been raised in the greenhouse than would be the case if either were of field origin. Should it become necessary to utilize field grown rootstocks, differences in physiological condition of budstick and scion should be reduced by allowing sufficient time to elapse between transplanting and budding. Otherwise "take" of buds will be disappointingly low.

Shield budding of walnuts has been highly successful in some instances in the nursery but almost a complete failure in others. During propagation of the walnut the bark of the budstick and rootstock must be slipping freely at the time of budding. If the bark of the budstick has tightened even imperceptibly at the time the shield, to which the bud is attached, is cut, a small piece of bud nearest the wood is apt to adhere to it. Walnut buds rarely grow when subjected to this type of injury.

The "take" of pistachio nut buds is always higher when they are obtained from the more vigorous of the current season's growth. Mango propagators in India point out that particular skill is required to enable the propagator to recognize the proper type of budwood to use, and to know when the stock plants are in the proper state of vegetative activity. Shield budding of mango is performed when the plants are coming into the flush, i.e., pushing out new leaves, as the bark can easily be separated from the wood at this stage.

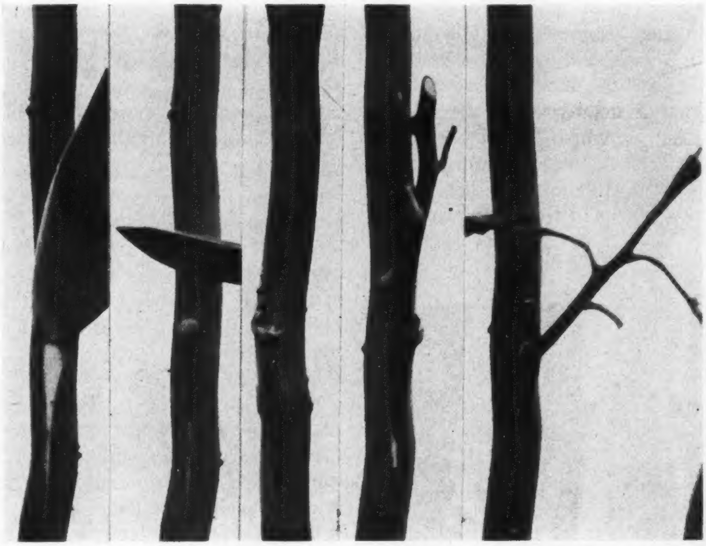

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Figure 11. Citrus budding. Opening T-cut on stock; inserting shield bud; bud after removal of rubber bands; use of sprig containing several buds; and shield with spur.

Budding

Budding is carried out by raising or removing a segment of the bark of the stock and inserting a segment of the scion containing a bud designated as shield or patch, as the case may be, into the wound thus made. Apple, pear, peach, mango, plum, pistachio nut, citrus, and many others, are readily budded by cutting a T-shaped incision in the stock, lifting the bark around the "T" and inserting the scion bud, which is attached to a shield-like section of the scion bark. (Figure 11). In budding the thick barked nut trees, more satisfactory results are usually obtained when a square or rectangular piece (patch) of the bark is removed and it is replaced by a similar sized piece of scion bark carrying a bud. Buds of this type are usually held tightly in place with waxed cloth or budding tape which is cut as soon as the patch is well healed, usually two to three weeks after budding, in order to prevent binding.

A shield containing a short spur-like growth is sometimes substituted for one containing a dormant bud, or in some instances a short section of growth containing several buds is inserted in place of the shield bud. These modifications are sometimes employed with citrus when the bark on the stock has started to tighten up. In all budding, the bud shield should be tied in such a manner as to press the shield firmly against the wood of the stock. Ordinary budding is restricted in time to the period during which the bark slips freely on the stock and in tem-

perate zones most budding in nurseries is done in mid-summer to late summer. Although the shield of the inserted bud unites promptly with the stock, the bud remains inactive until the following spring, at which time the stock is cut back close to the bud to force it out into growth. In the south, peach seed is planted early in the spring and the

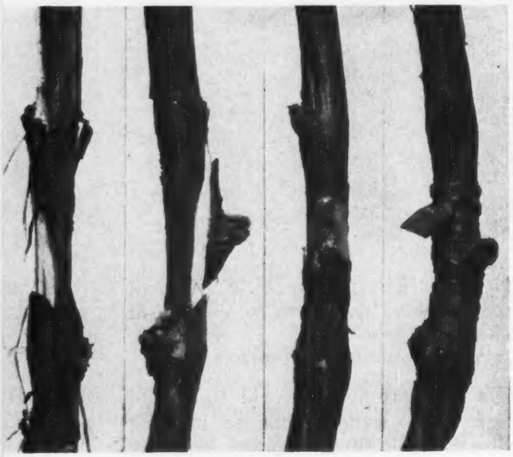

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Figure 12. Chip budding of grapes. Notch made in stock to receive bud; bud removed from budstick and ready for placement; bud in place; and bud tied and ready to be covered with soil.

seedlings are budded in June, sometimes a little earlier, breaking the stock over at the time of budding and removing it later after the bud has started to grow. This procedure is known as June budding. In Maryland, rootstocks of apple, peach, and pear, grown the previous season, are budded in the spring as soon as their bark begins to slip freely, using buds from dormant scions previously held in cool storage. As soon as it appears that the bud shield has united with the stock, the latter is cut back close to the bud to force it into growth that same season.

Excellent results have been obtained with chip budding small grape vines. Buds are selected from mature canes when bark color has turned brown and are worked on stocks actively growing at the time of budding. In removal of bud from the budstick, the first cut is made at the base of the chip deep into the stick at an angle of forty-five degrees. (Figure 12). The buds are placed on the stock just above the ground level, tied with rubber budding strips and covered immediately with six inches of pulverized soil. The following spring when growth starts, the soil is pulled away from the bud and the rubber strip is cut below the bud, allowing the top strands to hold the top end in place. The stock is cut off about one-half inch above the bud union and the vine again covered with loose soil to a depth of one to two inches to protect the bud and stock union from drying out.

Recent success attained in the air layering of some plants through the use of some of the newer plastic films, notable for their moisture retention properties, has called attention to their possible value in other types of propagation. Used as a protective covering on cherry buds set on stocks growing in the greenhouse, union of bud and scion tissue and subsequent growth of bud have been hastened. Budding of mango and macadamia nut in the nursery has been reported much more successful when the buds have been covered with plastic film. There will no doubt be other special cases where these plastic films may prove beneficial.

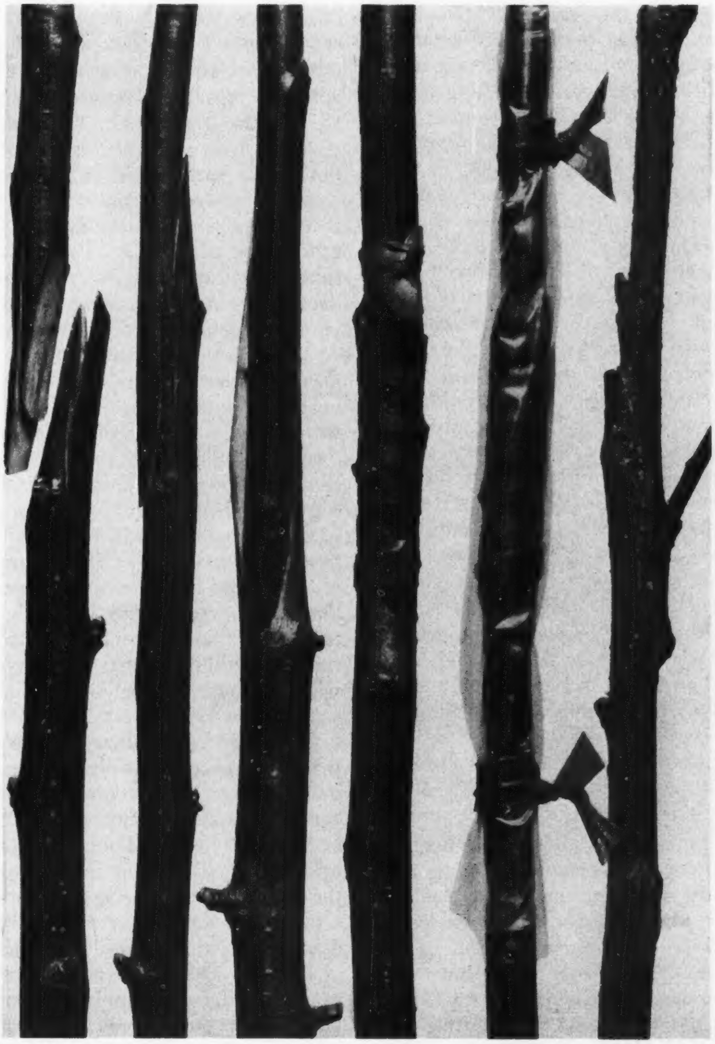

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Figure 13. Whip or tongue grafting. Stock below and scion above, cut ready for whip grafting; scion inserted, cambiums touching; on larger diameter stock, cambiums touch only on one side; tied in place with a rubber strip; covered with a polythene plastic film; completed graft after one season's growth.

Top Grafting

Top grafting is the usual method of changing from one variety of fruit to another. This type of grafting is confined to branches which are more than two to three inches in diameter, the smaller preferable, in order that the cut surfaces may heal fairly rapidly, thus reducing the chance of wood rotting fungi attacking the limbs. On younger trees top budding may be employed. Scions for grafting may be cut at any time while they are dormant. As soon as cut they should be wrapped in one of the plastic films and stored at a temperature of thirty-three to thirty-five degrees F. (If stored at a higher temperature they are apt to start growth.) In this stage dormant scions will grow when set in stocks which are considerably advanced in growth but the "take" of scions is uncertain when scion buds have already started to swell and grow.

The proper season for top-grafting trees depends on the method used. Bark grafting can be done only in the early spring after the bark of the stock has begun to slip. Cleft, whip, and side grafting may be carried out over a longer period, particularly if the scions are protected from drying out.

Whip or tongue grafting. This graft is employed in topworking young trees and in root grafting of apples and pears. Both piece-root or whole-root grafts are used for apples, but in case of pears, whole-root grafts have been found more satisfactory. The roots are dug in the fall and the grafting performed inside during the winter. Sloping cuts one and a half to two and a half inches long are made on the stock and scion. (Figure 13). Starting about one-third the way down from the tip a reverse cut about one inch deep is made. The two pieces are then fitted together so that the cambiums of each are in contact and then wrapped with nurseryman's tape. The edges of the adhesive tape are overlapped slightly so that the graft union is completely covered. Root grafts are usually stored until early spring in cool, moist sand, moss, or similar material, during which time a partial callusing of the graft union takes place. The grafts are sometimes calloused by plunging in damp peat or sphagnum moss at a temperature around seventy. When planted in the spring they should be placed deep enough so that only the upper bud is above ground level. As used in topworking trees, the tip of the scion and the graft union are covered with a protective coating of asphalt emulsion or a good grafting wax. Tying the graft is not necessary but if additional support is desired, nurserymen's tape is effective and much easier to remove than the waxed string formerly employed for this purpose. Tying with a rubber budding strip and covering with polythene film will accomplish the same result.

Cleft grafting. This method may be performed at any time during the dormant season, but is done to best advantage about the time the buds are beginning to swell. The graft is made by inserting the scion into a split in the stub left after sawing off a branch. Grafting of limbs over two inches in diameter should be avoided. Selection of a section where the wood is straight-grained and free from large knots or scars for six inches below the cut will make possible a straight and uniform cleft and thus help materially in fitting the scion. The splitting tool may be a special one with a concave blade designed to cut the bark first (thus avoid tearing it) and to aid in securing a

uniform cut in wood of twisted grain, or it may be an old knife. Some grafters trim the edges of the cleft with a knife but this is necessary only where the cleft is unusually rough. Smoothing the edge of the stub with a knife facilitates healing.

Scions for topworking are generally cut to three buds and topped about one-fourth inch above the top bud. The lower cut is made below the lowest of the three buds. Continuous and uniform bevel cuts are made to ensure the greatest possible cambium contact. It is not necessary that the scion be trimmed to a pointed wedge, for drawing the bevel out to a point may actually reduce the amount of scion surface in contact with the stock. Contact all along the cut surface is desirable but contact at the top of the cut end of the stub is essential to a good union. The outer edge of the bevel cuts on the scion should be made slightly below the level of the lowest of the three buds. Stored food reserves are greater at this point and callus formation starts here first and is more abundant. Setting the scion so the lowest bud is on the outside ensures the placing of the zone of richest callus formation nearest the point of cambial contact.

After the scions are inserted, all cut surfaces are sealed over with a good water base asphalt emulsion or one of the better waxes. Excellent protection from drying out can be obtained by encasing the unwaxed grafts in a polythene bag. (Figure 14). This can be left on the graft until the new growth from the scions fills it. The scions grow well in either case (Figure 15) but callus formation and wound healing appear to go on at a faster rate under the bags.

Cleft grafts of apple were made July 7, using current season's scion growth, and were covered with polythene bags to prevent drying out. The grafts grew well under the bags which were left on until late August. Although

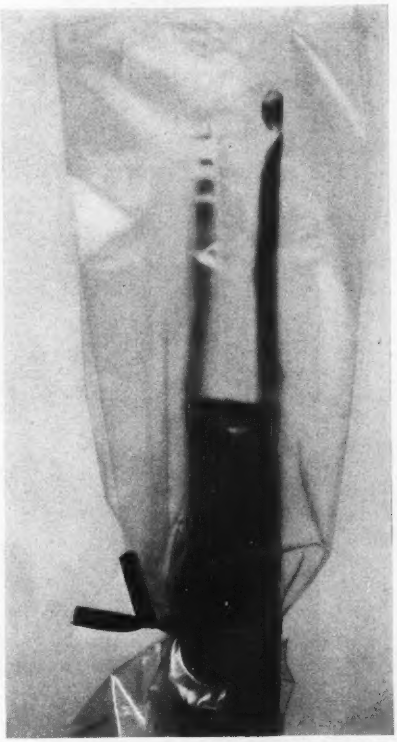

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Figure 14. Unwaxed cleft graft covered with a plastic bag and tied to the stock firmly with a "Twist-em."

callus formation was limited, due to lateness of growing season, union of stock and scion was satisfactory in all the summer grafts. All exposed surfaces were covered with asphalt emulsion or wax at the time the bags were removed.

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Figure 15. Cleft grafts. Growth of scions protected by grafting wax (left); growth of scions covered with polythene plastic bags only at time of grafting (right).

Bridge grafting. Trees may become partially or completely girdled at any period of their life as the result of mice or rabbit injury. This type of injury may also result from fireblight, borers, or winter injury. Street trees are continually subjected to this type of injury through careless use of lawn mowers and automobiles. Often the trees can be saved by bridge grafting. If injury occurs during the first three years of growth, it will be less expensive and more satisfactory in the long run to replace them.

Grafting is carried out in the early spring as soon as the bark of the injured tree will slip. Any of the methods used to unite the scion to the tree

involve the raising of the bark and this is not difficult during the period the bark is slipping. Scions similar to those cut for other types of grafting are used but should be somewhat longer. They are collected and stored in a dormant condition until needed. In areas where winter hardiness is a factor, scions of cold resistant varieties should be used.

A healthy condition of the wood surface of the tree at the points of contact is most important in bridge grafting. It has been shown that a large part of the callus tissue through which connection is established comes from wood rather than from the scions. Preparation of the injured area for grafting consists of removing all dead or unhealthy bark and painting the exposed surfaces to within an inch of the outer edges with a good protective covering.

There are various methods of setting the scions, one of which is shown in Figure 16. In this method, the scions are cut wedge shape at both ends, but the cut on one side is only about one half as long as that on the opposite side. A slit is made in the bark and the scions are then inserted, with the buds pointing upward, placing the longest cut surface next to the wood of the tree. The scions are then nailed in place. In bridge grafting young trees, it is particularly important that the scions be cut slightly longer than the space to be bridged, so that they will bow out and allow for the swaying of the trunk.

In other methods, a bevel or sloping cut is made on one side of the scion only. The scions are then inserted under a flap in an L-shaped cut in the bark and held in place by nailing through the bark and scion. Another method is the inlay; in this, a section of the bark is removed and the scion inserted. Success in the various methods of setting the scion depend in all cases on contact between the surface of the wood of tree and bevel or sloping cut on the scion. Scions should be set about two inches apart. The remainder of the cut or exposed surfaces should then be waxed.

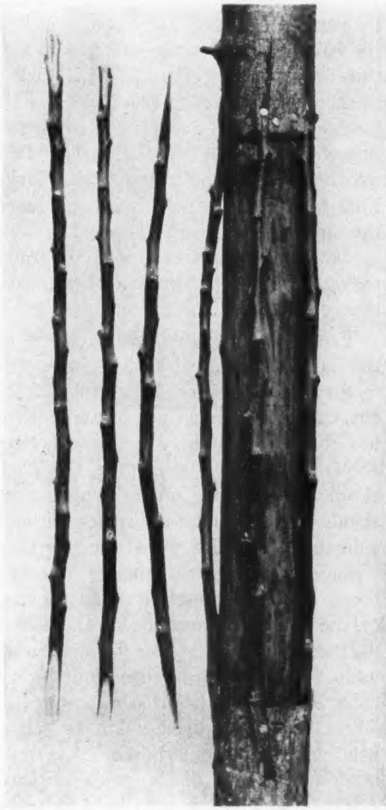

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Figure 16. Bridge grafting. Three views of scion preparation (left); scions inserted and nailed. Scions are cut long enought to have a spring to them after insertion.

Bark grafting. The bark graft is used in place of the cleft graft by some propagators because it can be done without splitting the stub; it is thus felt that decay organisms cannot gain a foothold as readily. It is probably preferable on some stone fruits, for it does yield a higher percentage of scion take, but this is not the same in pome fruits, such as apple. Bark grafting cannot be performed until early spring when the bark of the stock begins to slip and this necessitates collection and storing of dormant one-year scion wood. This method has been recommended in the prevention of die-back of apple that usually follows the cutting of a large limb to a side branch. In such cases the subsequent growth of graft is kept in bounds by pruning, allowing only enough growth to stimulate healing of the injury.

There are various modifications of the bark graft, all of which give satisfactory results. The scions are usually cut, care being taken not to make them too thin or they may break off after growth starts. The slit in the bark should be just long enough so that the scions can be pushed into place without splitting the bark. The scion is then placed in the center of the slit, one nail being driven through it near the top of the stub and another at the lower part of the scion. Flat headed, wire nails five-eighths to three-fourths an inch long have been satisfactory; if larger scions are used, a longer nail is used. Although not shown in the illustration, the bark of the stock on each side of the scion is also held in place by nailing. In bark grafting citrus trees, the stub is taped around to hold the scions in place. After the scions have been set, all exposed surfaces of the stump and scions are covered with a protective covering as in other grafts.

Side grafting. Side grafting has been found more effective in the greenhouse than T-budding in getting citrus established when the stocks are not in too good of a condition. It has also been recommended for the propagation of magnolia, Japanese maples and flowering dogwood, using dormant scions on slightly started stocks, usually with the buds just beginning to swell. (Methods of handling side grafts of these ornamentals were discussed in detail by Richard Fillmore in the December 1, 1951 issue of the *American Nurseryman.*)

Side grafting has been found most useful for branches of fruit trees around one inch in diameter, which are too large for whip grafting, yet too small for cleft or bark grafting. The scion is usually wedge shaped as shown in Figure 17. In branches around one inch in diameter the oblique cut is made with a heavy knife or chisel, the stock being bent to open the cut to insert the scion. The scion is then driven into place so that the cambiums touch. The spring of the wood will usually hold the scion in place but in addition small nails or string should be used. The graft is wrapped with rubber bands or tape. After budding or side grafting of citrus the tops are lopped over about six inches above the bud or graft but not detached. (Figure 18). The stock top may be gradually reduced or partially girdled just above the bud but it is not cut back to the bud or scion union until it is evident that the buds have started growth. In the case of other fruits, the top of the grafted branch is immediately cut off just above the base of the scion. All cut surfaces are then covered with a protective coating.

After-treatment of grafted trees. Care of topworked trees is important

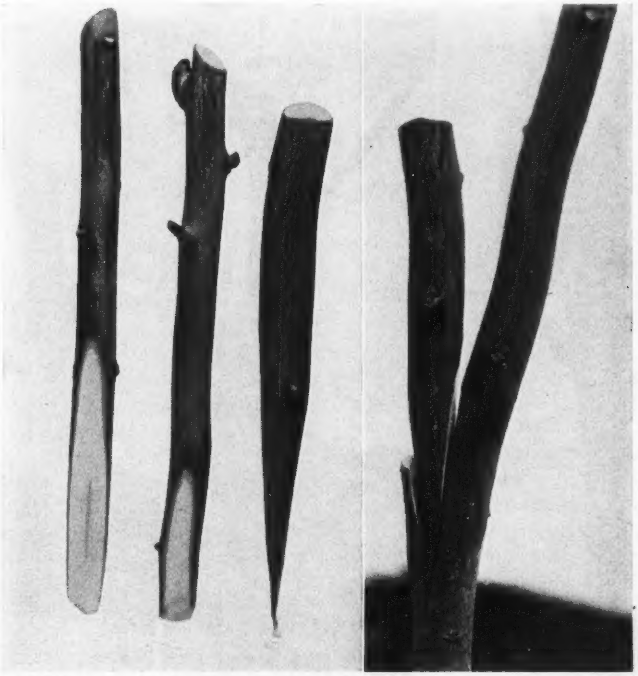

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Figure 17. Side graft on citrus. (Left) three views of scion; scion in place, showing method of cutting stock. On stock of large (1 inch) diameter, the scions are cut on the same on both sides and the cut into the stock is more oblique.

if subsequent breakage of grafts is to be avoided. In some instances, as in the case of apple and pear, unworked branches are left to shade the exposed trunk and laterals to prevent sunburn. If all branches are removed the tree is thoroughly whitewashed as a preventive. In the western part of the country, paper bags are sometimes placed over the grafts to protect the scions from the sun, especially if the work is performed late in the spring when warm weather is likely to occur. Heavy, durable bags are used and holes are cut in the corners to provide ventilation. The grafts should be checked at intervals and cracks in the protective coatings should be resealed to prevent decay organisms from entering the wood. Water sprouts appearing below

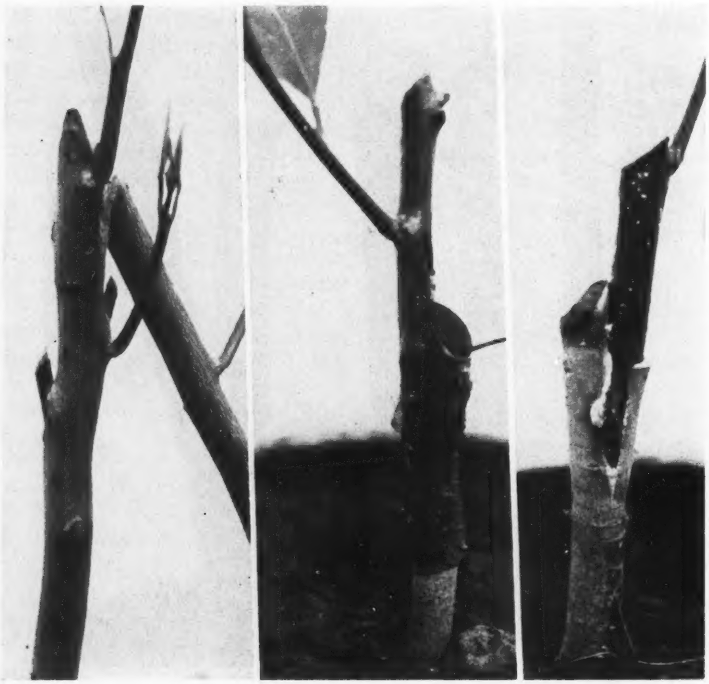

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Figure 18. Side graft on citrus. Stock is broken over and cut back until scion growth is stimulated; stock removed above graft (showing also method of tying and waxing at time graft is made); rubber strip removed to show callusing of scion and stock.

the graft may choke it out. Thinning some out entirely and cutting back those left to protect the trunk from sunburn is the usual procedure.

The treatment of the scions after they start growth consists of selecting and training those scions to be left and the reduction of the others while they are contributing to the healing of the stubs. Growth of the scions saved should be pruned as little as possible in order to encourage rapid growth. Young grafts of walnut and the pistachio nut tend to make a rapid extension of growth, willowy in nature, which need to be supported with laths, bamboo poles or strips of wood for a few years. Pinching back and thinning out the new shoots of others, the apricot for example, accomplishes the same purpose.

Layering

John L. Creech[1]

Layering of plants has attracted considerable attention in recent years due to the success resulting from wrapping air layers in plastic film to reduce moisture loss. Seemingly new because of this adaptation, layering is actually a very ancient practice. Cato, 234-149 B.C., in his *De Re Rustica,* described it and horticulturists have elaborated on the subject throughout the subsequent centuries. Prior to the advance caused by the use of plastics, layering had almost become a vanished art since the trend in propagation has been toward rapid methods, of which new plants are the ultimate goal. Layering is slow, frequently requiring up to two or more years before a new plant is produced. As a consequence, few American nurserymen use layering. Amateur propagators, following the lead of the commercial growers, have also ignored this technique and have attempted to root everything from cuttings, frequently with failure due to a lack of specific knowledge or of essential equipment.

It must be recognized that there are instances where layering is a major means of propagation, particularly for the increase of clonal rootstocks such as are used for dwarfing fruit trees. Furthermore, in European nurseries layering is a principle means of propagation and one such establishment roots over two hundred species and varieties by layering. It may be that here in America we do not have the peculiar combination of moist atmosphere and soil that provides the uniformly excellent results that are obtained in nurseries of the European lowlands in particular. Layering has never been followed in this country as closely as it has in Europe, in any event.

Natural layering is a common occurrence among some species, particularly ericaceous plants growing in moist, shaded locations. The lower branches become covered by strata of decaying leaves and very soon root in this medium. When one lifts such branches from the leaf mold, rooting may be extensive. These branches can be cut away from the parent plant and established in a coldframe or similar protected location. This should be done either in the spring or early fall.

Although not as frequently observed, conifers are also reported to layer naturally. Old specimens of spruce, hemlock, and juniper growing in open sites that permit healthy lower branches have been described as ringed with young plants developed from branches that have been buried for several years. These branches, gradually covered by plant debris, have rooted and turned up-right to assume the erect form essential to normal tree growth.

Perhaps the most interesting example of natural layering is that reported by Little (*Ecology* 25:112-113. 1944) where a number of species rooted after the branches were bent to the ground by a heavy snowstorm. Among those that layered readily were *Clethra alnifolia, Cornus florida, Acer rubrum,* and several species of viburnum.

Various modifications of natural layering have been devised by propagators

[1]Horticulturist and Superintendent, United States Plant Introduction Garden, Glenn Dale, Maryland.

to obtain more rapid rooting, better shaped plants, and a greater yield. These are described thoroughly in all plant propagation texts, many with duplicate names. The chief categories of layering are as follows: simple branch, serpentine, mound and trench, tip, and air or Chinese (marcottage). The amateur, interested in propagating relatively few plants should regard simple branch layering and air layering as his principle methods.

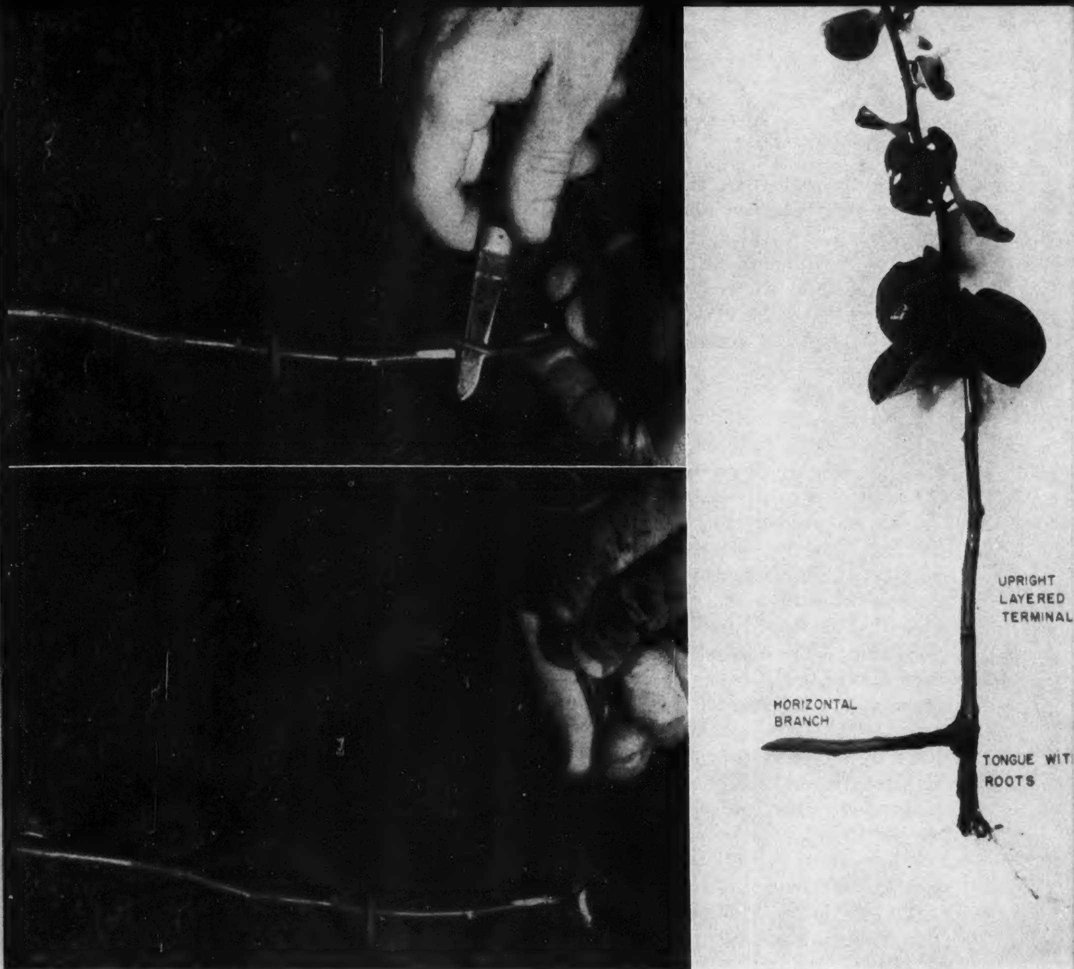
Simple branch layering differs little from natural layering except for the manipulation of the branch to stimulate rooting and to obtain a better shaped plant. Layering is performed either in the spring before the buds break or after the wood hardens in late summer. The basis for such "timing" is that root activity is greatest in the cooler parts of the growing season. A branch suitable for simple layering is low and sweeping and can be bent to the ground without difficulty. The ground beneath the plant should be improved by adding peat and sand or leaf mold to the surface and cultivating it into the ground. The objective is to produce a porous, friable medium that will hold moisture and yet pack tightly around the layered branch.

The branch is first prepared for layering by making a wound in its upper side cutting toward the tip. Location of the cut will be governed by the size of the branch but it usually will be located about twelve inches from the tip. The branch can now be pegged into the medium at a point between the trunk and the wound. To bring the layered branch to an upright position, firmly twist the branch at the wound and bend it vertically at the same time. Few texts stress this point but it does eliminate the danger of snapping the branch which sometimes occurs if the branch is wounded on the under side. A second peg may be required directly at the point of the wound or a flat stone can be placed over the branch. (Figure 19).

Peat and sand or leaf mold is mounded over the layer and packed to support the stem in the upright position. Straw or leaves, spread over the entire surface, will aid to retain moisture but the layers should be checked frequently to be sure that the medium does not dry out. Shrubs that root easily can be removed by the end of the first autumn. In this group fall dogwods, crabapples, quinces, Lonicera, viburnum, and many similar woody shrubs. More difficult types like the maples, the deciduous azalea, magnolia, and conifers must be left through the winter and removed either just before the buds break in the spring or during the next autumn. The rooted layers can be planted in a coldframe or shaded greenhouse in a peat-sand mixture. Layers removed in the fall may defoliate but root activity will continue for several weeks and when dug the next spring, the layers will have a well-developed root system.

Air layering is really more suitable to the gardener since any branch within reach can be propagated and there is not the necessity of preparing a layering medium under the plant. It may be that this has caused the continual experimentation to improve the method. From a beginning when air layers were used only in greenhouses or in the tropics (without continual attention), we can now employ air layering under almost any climatic condition.

Before the advent of plastics, various means were used to keep layers moist. Rubber tubing was sometimes wrapped



TAYLOR

Figure 19. Steps in branch layering. Left: Upper, stem pinned to peat showing how the cut is made; Lower, twisting layer into vertical position. Right: Rooted layer. Note that callus has "welded" branch to perfect right angle and that the rooting has first occurred on the tongue.

around the moss or layers were encased in waterproof paper with a glass wick running into the moss from a water bottle. None of these methods really were efficient for the moss still dried out or the water bottles were cumbersome to attach to the branch. Finally, in 1947, W. R. Grove described the manner in which he used plastic film (now a patented process) to make a successful waterproof wrap around the moss. Using it, he rooted a great number of tropical trees and shrubs. Since that time, plastics have been tried under various climatic conditions and a wide range of woody plants have been layered by this method. The Arnold Arboretum has described its results with a long list of plants, many of which are considered

difficult to root from cuttings. The results were observed only at the end of the first year, however, and many species were listed as not rooting. Since that time, we have observed that many shrubs require two or more years to air layer, a fact already determined in mound layering.

Although there are many kinds of plastics, not all are suited for air layering. It is essential that the film be low in moisture transmission and at the same time relatively high in carbon dioxide and oxygen permeability. Also, the film must be sufficiently tough to withstand the variations in climate that occur during the year. Typical of the films that are suited for air layering is polythene. The Arnold Arboretum used film of 0.004 inches thickness but the film can be obtained in the whole range 0.002-0.008 inches. The film offered by the successors to the late W. R. Grove is sold under the name Airwrap and other appropriate plastics are sold under such trade names as Alathon, Pearlon, Tralon, Howard-seal and Polyethylene.

The air layer is prepared in a few simple steps, made either on last year's wood or even older stems. (Figure 20). Older branches may not only be slower to root but also more difficult to establish after they have been removed. The stem must be wounded, either by a slicing wound as for branch layering or by girdling. Early horticulturists pointed out that the wound interfered with the movement of sap but a more modern interpretation would be that the natural hormone transport was interrupted. Ringing with copper wire has not been used to any extent in air layering yet in mound layering studies this method was far superior to girdling. Either method produced better rooting than when the stems were not wounded at all. Ringing would eliminate the problems that accompany wounding for sometimes the branches die or can be broken off by high winds. A growth regulating compound is dusted into the wound (such as is used for rooting difficult cuttings, Hormodin No. 3) and a handful of moist sphagnum is wrapped around the stem, thoroughly covering the wounded area. This is enclosed in an eight by ten inch sheet of film that is tightly wrapped so that it overlaps. Tied at top and bottom, the film will keep the moss moist through the entire summer and layers do not need to be disturbed until they are rooted, regardless of the length of time required. Actually excess moisture becomes a problem if the moss is not squeezed dry prior to application. Ties may be either waterproof electricians tape, rubber bands or florist plant ties. Tape may serve best since it can be applied to the stem above the film and then down over the top of the plastic to close the top sufficiently to prevent rain from seeping down into the layer.

Although layers applied in the spring may be ready to remove the following fall, some must be left through the next

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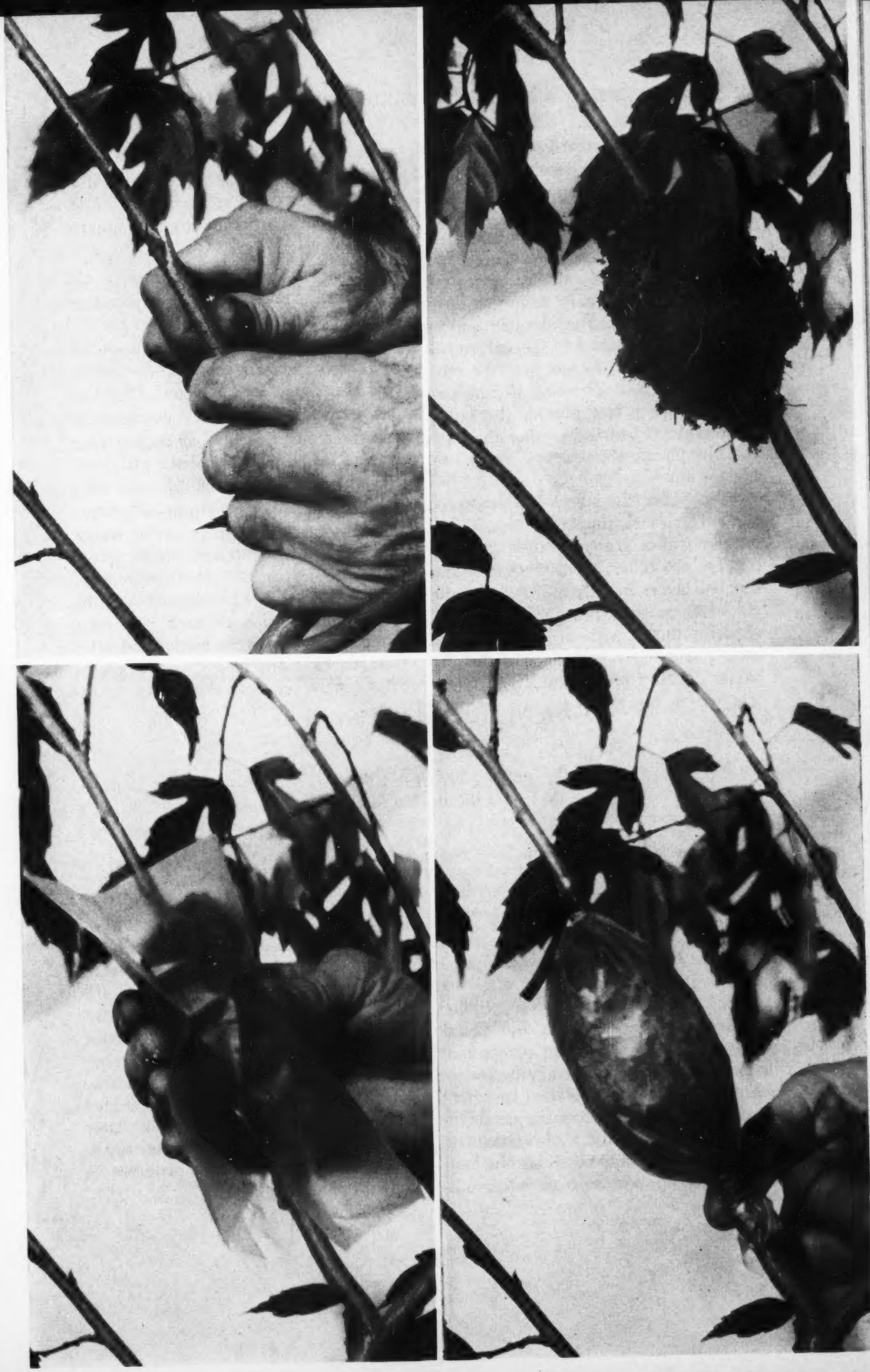
CREECH

Figure 20. Steps in air layering. Top: Left, wounding a branch prior to application of rooting powder. Stem can also be girdled. Right, sphagnum moss, when slightly moist, is compressed around the wound. Bottom: Left, polythene film is then wrapped around the stem so that it overlaps sufficiently to make a moisture-proof container. Right, the polythene is twisted around the stem and tied at top and bottom with rubber budding strips.



year to root satisfactorily. This is true of holly, lilac, the deciduous azaleas, and magnolia. Layers with only few roots may be left on the plant over winter safely and although the layers freeze almost solid during the winter, the roots survive and continue to grow the next spring. *Magnolia kobus,* in particular, requires a considerable time to root. Layers applied in the summer of 1951 did not start to root until the summer of 1953 and all rooted during that year. During this period, the layers were undisturbed and neither the moss nor the plastic showed any visible deterioration.

Removal of the layers has presented some discussion, for layers may die after removal even though they are rooted. On the other hand, the writer has severed layers in July and August and placed them in a peat bed in a cool, shaded pithouse without loss of a single leaf. Particularly striking was this behavior in *Ilex opaca* and *I. pedunculosa* where layers up to two feet tall with a sparse amount of roots were handled in this manner. A month after removal, a massive root system had developed, proportionate to the amount of top development.

Perhaps more important than the size of the layer and the number of roots is the vigor of the layered branch. Plants of *Callicarpa dichotoma* were grown in pots of sand so that they were low in vigor. Air layers were applied to each plant in the usual manner except that no hormone was added. One-third of the plants received no fertilizer, one-third received applications of eight grams of sixteen per cent nitrogen per gallon of water, and one-third received twenty-four grams of sixteen per cent nitrogen per gallon of water. The nutrient solution was applied twice to each pot, once when the layers were made, and after four weeks. The layers were removed after ten weeks with the following results.

TABLE 1
Rooting Of Layers Relative To Stock Plant Treatment

Stock Plant Treatment	Number Of Layers[a]	Heavy Rooting	Light Rooting	None
High nitrogen solution applied	19	3	14	2
Low nitrogen solution applied	19	9	8	2
No nitrogen solution applied	19	7	11	1

[a]Applied June 15, 1953; removed August 25, 1953.

During the period that the layers were on the plants, those plants that had received the highest application of nitrogen made considerable succulent growth while those receiving no fertilizer application produced almost no new growth. Plants receiving the lower nitrogen application were intermediate. The layers were cut from the plants and placed in a peat bed. Immediate defoliation of most of the plants resulted. When the transplanted layers were examined six weeks later those receiving the low nitrogen application had made the most progress as shown in the table below.

TABLE 2
Development Of Layers Relative To Stock Plant Treatment

Stock Plant Treatment	Layers With New Roots And Foliage	Layers Dead Or Doubtful
High nitrogen solution	4	15
Low nitrogen solution	15	4
No nitrogen solution	7	12

Although this is only a preliminary study relating rooting of layers to stock plant condition, it does indicate that the vigor of the plant considerably influences both the rooting and the subsequent progress of the layers after they have been removed. Quite likely, very succulent, rapidly growing branches on large specimens would not be the best layers and, conversely, plants suffering from complete lack of fertilization would make poor subjects to layer.

Undoubtedly, air layering with plastics is still far from being a common propagation technique but this does not alter the fact that a larger plant can be produced in a given length of time (between one and two years) than by any other own-root propagation technique. At present, the scope of air layering extends mostly as far as the garden of the amateur, but with further study to assure more uniform results, and to standardize the procedure involved, it may be a reliably successful commercial method and the counterpart of the extensive mound layering system that is in vogue in European nurseries.

Growth Regulators

VERNON T. STOUTEMYER[1]

The introduction of plant growth substances as an aid to plant propagation, particularly with the rooting of cuttings, is an important development of the last twenty years. It is noteworthy as an illustration of an immediate and practical application of important research in plant physiology which developed in the European laboratories of Went, Boysen-Jensen, and others.

These materials are now widely used, since they unquestionably promote rapid and heavier rooting of cuttings which ordinarily root without difficulty. The extent to which they are helpful with the really difficult cases is less certain and there are divergent viewpoints on the question. An excellent manual on propagation, published in 1948, devoted only two pages to the subject, although it discussed the propagation of many difficult plants.

Although there are exceptions, these substances have not generally made easy the rooting of cuttings of deciduous, hardy fruits or forest trees. Treatments do not eliminate the need for special knowledge and skill on the part of the propagator. These substances have

[1]Head, Department of Floriculture and Ornamental Horticulture, University of California, Los Angeles, California.

a great usefulness, in spite of the fact that they have not solved all of the problems of propagation. Much still remains to be learned regarding the rooting process.

Many chemical substances producing plant responses which permit them to qualify as plant hormones do not aid in root formation. Until recently, most of the compounds used for cuttings were indole or naphthalene ring compounds with fatty acid chains. Much of the original work on plant auxins or hormones was done with indoleacetic acid, a compound known to occur in plants. Although indoleacetic acid produces good rooting, indolebutyric acid and naphthalene acetic acid are often more effective and have been widely used in commercial preparations. The potassium salts of these compounds have sometimes been used because of the greater solubility in water. Various esters and amides have been used with closely similar results. The different compounds have sometimes been observed to form root systems differing in type. The indole compounds usually tend to form a more fibrous and minutely divided root system than the naphthalene compounds.

From the standpoint of low cost and a high degree of effectiveness at low concentrations, several of the chlorophenoxy acids are unsurpassed. The well known herbicide 2,4-D, (2,4-dichlorophenoxyacetic acid), is excellent for promoting rooting, but may inhibit bud growth undesirably. The related compound, 2, 4, 5-T, (2,4, 5-trichlorophenoxyacetic acid), is even more effective in promoting root formation and does not have this disadvantage. Both 2, 4-dichlorophenoxy propionic and 2, 4-dichlorophenoxy butyric acids are also useful and may assume importance in the future. Mixtures of two different compounds seem occasionally to have a distinct advantage over one compound used alone.

Methods Of Treatment

Soaking in dilute solutions. Various methods of introducing the chemical in the cuttings have been used. Some are so cumbersome that they have no chance of being used commercially. The method of treatment used largely at first was to immerse the bases of the cuttings in dilute solutions of the chemicals for periods of time up to twenty-four hours. It is seldom used today, however, but it is particularly useful with difficult cuttings where other substances such as sugar, nitrogenous compounds, or vitamins, are combined with the growth substance.

When solutions are prepared, it is necessary to dissolve the growth substance first in a suitable solvent. Water may be used with the potassium salts of these substances, but many of the others are not easily soluble in water. With these, the crystals of the growth substances are dissolved first in methyl (wood) or ethyl alcohol, using a small quantity to make a concentrated stock solution which is then diluted to the desired concentration.

Variations in humidity, or the presence of strong drafts, will cause a considerable variation in the amount of the chemical taken up by the cuttings. For this reason, some have placed a large bell jar over the cuttings during the treatment in order to standardize the uptake of the chemical.

Using indolebutyric acid or naphthalene acetic acid, the concentrations useful for most plants will range from five or ten to fifty or sometimes even one hundred milligrams per liter, depending on the species of plant and the type

of cutting. Concentrations around the latter range will sometimes cause excellent rooting of hardwood cuttings, although generally this type of cutting has not been very responsive. Likewise, growth regulating substances have not been very beneficial with root cuttings.

One variation of the base immersion treatment is the immersion of the entire cutting during the treatment. Good results have been reported for cuttings of conifers with this technique. Placing the cuttings under a vacuum in a bell jar during this treatment also allows more of the solution to be absorbed. Raising the room temperature during treatment will also promote uptake. The solutions can be once reused, if reused immediately, but the second time of using the solution may need to be prolonged somewhat to obtain comparable results.

Dipping in concentrated solutions. One of the most rapid and effective methods of application is to immerse the bases of the cuttings in concentrated solutions of the growth regulating substances.

The solvent nor the concentration does not appear to be critical factors. A fifty per cent aqueous solution of either methyl or ethyl alcohol has been used as the solvent with excellent results. Indolebutyric acid or naphthalene acetic acid, concentrations ranging from one to twenty milligrams of the growth regulator per milliliter (cubic centimeter) of the solvent, will cover the requirements of most cuttings.

In order to reduce contamination and dilution of the solvent, only a quantity barely sufficient to be usable immediately should be removed from the bottle of the stock solution and any used material remaining should not be poured back with the stock solution.

This method of treatment is simple and effective and is well adapted to practical use. It is preferred by some propagators.

Powder preparations of growth regulating substances. Growth regulating substances in a powder carrier have been very popular in practical use. They are relatively stable over considerable periods of time if properly stored. A small quantity of the powder needed for immediate use should be taken from the supply and used in a shallow container to avoid the dipping of the base of the moistened cuttings in the stock and to prevent contaminating or moistening the entire supply. Powders can be reused, but once used, they should be kept in another container to avoid the introduction of moisture in the main supply of the material. One method of preventing wetting of the unused stock powder during treatment is to apply the powder to the base of the cuttings with a dust atomizer of the type used by surgeons. This also eliminates the danger of spread of diseases by the former treatment.

A choice of different preparations is available commercially. Few may be interested in making their own mixtures. This can be done easily by dissolving the crystals of the growth substance in sufficient wood alcohol or other volatile solvent to wet the required amount of talc powder, or other carrier, mixing thoroughly and drying. A finely divided talc should be used for the greatest effectiveness of a given amount of growth regulator. Other inert materials, such as bentonite, wheat or soybean flour, and powdered charcoal have been used successfully.

Concentration Of Treatment

One of the important factors in the use of growth regulating substances is the use of the appropriate concentration regardless of the method of application. The use of too low a percentage may result in a weak or non-evident response. On the other hand, too high a concentration can cause severe damage to the cuttings or even complete losses from death.

As a general rule, about three different levels of concentrations can be used with any of the growth regulating substances to cover all ordinary requirements, although, ideally, a greater range of concentrations could be used. Cuttings in general root best with concentrations of growth regulating substances which are not far below the toxic level. This is particularly true of those cuttings which root with greatest difficulty. In cases where the probable responses to a treatment are unknown, however, it may be best to be cautious, since cuttings can always be retreated at higher concentrations.

Although concentrations for the various carriers for treatments do not hold in a straight line relationship between each other, a reasonable approximation for such materials as indolebutyric acid or naphthalene acetic acid, a talc mixture of one part per one thousand parts of fine talc, or a quick dip using one milligram of growth regulator per milliliter of solution, or soaking in a dilute aqueous solution of five to ten milligrams per liter for twelve to twenty-four hours in an average room may all be considered relatively weak applications. The use of concentrations four or five times greater may be regarded as being in the intermediate range, and those ten, fifteen, or even twenty times greater than the lowest concentrations, can be considered as being about the maximum and would be applicable only to special cases. The strongest concentrations would be applicable largely to some woody lignified plants propagated by nurserymen such as the camellia, rhododendron, some cuttings of coniferous evergreens, such as hemlocks. The intermediate ranges would be suitable for a great many plants of both nurserymen and florists. The lowest concentrations would apply particularly to florists plants of a herbaceous nature.

The compounds used for weed killers, 2,4-D and 2,4, 5-T, are among the most effective compounds known for promoting the rooting of cuttings. They must be used in much lower concentrations, however, than would be usual for indolebutyric acid or naphthalene acetic acid. The former of these compounds, and also 2, 4-dichlorophenoxy propionic acid and 2,4-dichlorophenoxy butyric acid applied to bases of cuttings in a dilution of 0.5 mg. per gram of talc have produced outstanding rooting of cuttings of *Pachysandra terminalis, Ligustrum quihoui, Ilex crenata convexa,* and *Cinchona ledgeriana.* The two latter compounds produced less visible injury to the cuttings.

The most effective compound of all at very low concentrations is 2, 4, 5-T, but precautions are needed to avoid injury because of the extremely high activity of this compound.

A great many observations of concern have been recorded for various species of cuttings. These have been summarized occasionally. A list of books most readily available containing such compilations is given at the conclusion of this paper.

Such compilations of horticultural experiences with growth regulating

substances are very useful as a general guide, but certain factors not recorded may be required by the amateur to fully evaluate their application. As an example, the writer once took cuttings from bushes of the same variety of azalea growing not more than thirty feet apart with identical exposure to the sun. In one instance, the gardener had watered the bushes liberally which had produced a soft, new growth. In the other, no artificial irrigation had been given so the cuttings were much harder. A concentration of growth substance in a powder preparation, which gave perfect results with the latter cuttings, was highly injurious to the softer and more succulent cuttings from plants which had received a heavier supply of water.

Supplemental Treatments

A considerable number of modifications of treatments with growth substances can be made which are often helpful in promoting rooting. The most useful for woody materials which root with difficulty is the use of wounding. This may be done by various methods, including slitting the base of the cuttings, or the bark of the lowest portion, in some manner to facilitate the entrance of the chemical. This aid is applied prior to the application of the growth regulator.

Another addition to treatments with growth regulators which has often been beneficial is the use of some of the newer fungicides, particularly the organic types, such as Phygon XL, Arasan, and Fermate. These are readily incorporated in the talc dust mixtures. They have been used also in aqueous treatments. Commercial preparations using fungicides have been available for several years.

Unquestionably, many of the vitamins will inhibit the rooting response under certain conditions. Results are apt to be inconsistent and difficult to reproduce. Some exaggerated claims have been made for the use of vitamins in propagation, but the extent of their value has been very difficult to determine.

Mineral nutrient solutions, applied initially to the cuttings, or to the cutting medium, have often been observed to promote rooting. This is particularly true with nitrogenous compounds. Likewise, treatment of cuttings with cane sugar, before, or with the application of growth regulating substances, has been useful. Two to four per cent aqueous solutions used for soaking the bases of cuttings have worked well.

Temperature

One very important factor in the response of cuttings to growth regulating substances is temperature, both of the air and in the rooting medium. The latter is particularly important and is usually held somewhat higher than the air temperature. For most cuttings, a range of sixty-five to seventy-five degrees would be suitable, although higher temperatures should be used for some tropical plants.

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Apparatus And Materials

Vernon T. Stoutemyer[1]

The mastery of a few reliable propagation techniques will extend considerably the range of achievement and enjoyment in gardening. In some cases, however, it will be wisest not to attempt too much. Important trees, certain coniferous evergreens, or other slow-growing plants, most often should be purchased in suitable sizes at a nursery, since precious years of time once lost in the garden can never be made up. The gardener with a cramped budget, however, can often rival his more affluent neighbor by virtue of his skill in propagation with the exercise of a little patience.

For the more adventurous gardener, the use of propagation techniques provides many plants which are not available in commercial nurseries. Dealers in rare seeds here and abroad provide much material not obtainable otherwise. Seeds of many items can be obtained by exchange. Even those gardeners interested in the ordinary run of bedding plants will find it possible to grow an array of choice varieties which cannot be obtained at the ordinary seed store or nursery. Those with sufficient space and leisure to take up the fascinating hobby of amateur plant breeding will do well to standardize on a few simple and reliable methods of germinating seeds and handling plants.

All amateur propagators should be aware of the plant patent laws which cover many of the recent horticultural plant introductions that are propagated vegetatively. All such plants are sold with a label that calls attention to the restriction of rights to propagate. Multiplication of such varieties by the amateur is a violation of the agreement under which such plants are sold, and will be avoided by conscientious and ethical gardeners, since violations tend to break down the plant patent system. This wise law perhaps has been responsible for much of the great improvement in horticultural varieties of many plants in recent years. Because of the protection given to the originator, many nurseries have enlarged their breeding programs. At the present time, a large proportion of the rose bushes sold by nurserymen are of patented varieties and each year the trend increases. Where there is a doubt about the status of a recent horticultural variety, a nursery catalog should be consulted before it is propagated by cuttings or grafting and budding. The present laws do not apply to plants grown from seed.

Bell Jars Or Frames

Bell jar propagation in the open ground is a simple technique which will often give excellent results with greenwood cuttings, and sometimes hardwood cuttings or root cuttings as well. This method of propagation has been described in old propagation manuals. We have all seen the gardener who has considerable success in rooting cuttings of roses, camellias, or other plants in a shady border or on the north side of a building under an inverted Mason or pickle jar. Bell jars and glass or plastic covered frames of larger dimensions may be used to ac-

[1]Head, Department of Floriculture and Ornamental Horticulture, University of California, Los Angeles, California.

commodate more cuttings and will give closely similar results. The amount of rooting may be variable due in part to the chances of attack by fungi, but often the percentage of plants striking root is sufficiently great to be worthwhile. The incorporation of considerable sand in non-sandy soil will increase the soil porosity and aeration. Treatments of the cuttings with growth substances will be helpful. Moderate shade is advisable; since bell jars or frames are exposed to strong sunlight, the relative humidity will decrease greatly. For cuttings of many kinds of plants, exposure to relative humidities much below seventy-five or eighty per cent may be hazardous.

Mechanical Humidification

During the past few decades the use of mechanical humidification of propagating frames in greenhouses or clothhouses has come into extended use. Whenever this method is used, great care must be taken to harden off the rooted cuttings gradually or heavy losses may be expected. In those areas where outdoor temperatures are suitable for the cuttings in question, success has been attained in rooting cuttings in the open air with the protection of a water spray to prevent wilting.

These installations can be very simple and inexpensive, and will permit the fortunate gardener who has a small greenhouse to be absent all day, confident in the knowledge that cuttings in a propagating bench or frame will be in good condition regardless of changes in weather during the day. For enclosed frames of relatively small size, the baffle nozzles often seen over vegetable displays in markets can be used, although they are not particularly efficient and are wasteful of water. The various types of compressed air nozzles cover a larger area, but require too expensive and complicated equipment for amateur use. The types of nozzles which require only the normal pressure of the water line for operation are more practical. A strainer with a fine screen which can be easily removed for cleaning should be inserted in the water feed line, or considerable difficulty may be experienced with stoppage due to particles of sediment which collect in the orifices. A few nozzles are available which are self-cleaning and have a needle which passes through the orifice when the water is turned off and on.

Whirling sprinklers of the type used for watering can be used, but, unless the orifices are small, the quantities of water used will be excessive. From the standpoint of economy, some of the motor-driven centrifugal atomizers are exceedingly efficient and consume small quantities of water and electricity. They are useful for frames, but unless they are very large and ventilation is restricted, they may not cover much area of greenhouse space in hot weather.

Humidification is not needed at night in most situations, but does not appear to be harmful. One might expect trouble from fungi in the wet conditions provided by mechanical humidification, but this does not seem to be the case. The usual experience has been that troubles due to fungi are reduced.

Plastic Material

The introduction of plastics has resulted in the use of this material in air layering and grafting, with results sufficiently striking to warrant attention in the horticultural journals. They have greatly facilitated the safe shipment of horticultural materials over

long distances. Doubtless the end of applications has by no means been reached. Some propagators have placed flats of germinating seeds or rooting cuttings in closed plastic bags as a means of reducing loss of moisture. Since this eliminates a great deal of the need for personal attention, the amateur propagator operating on a small scale will find many uses for plastics.

TAYLOR

Figure 21. Hardwood cuttings of Poplar after shipping in a polythene bag. Note that cuttings have both callused and rooted in transit. Shipping time was fourteen days.

In fact, a plastic bag may be used for the rooting of cuttings in an ordinary room. The bases of the cuttings may be placed in a moist rooting medium and the sealed bag may be placed on a table in an ordinary living room sufficiently near a window to provide adequate light. Excellent rooting of small quantities of cuttings may be obtained by this method.

New Rooting And Seeding Media

Several new materials have been introduced in recent years, which, because of their superior water retention and other favorable qualities, have reduced the necessary attention required, and have often yielded noticeably better results than are usual with more familiar materials. Vermiculite is a heat-expanded micaeous mineral which has great absorptive powers. The size of particles of this material has a considerable influence on the results. The same is also true of perlite, which is likewise a mineral common in the Western States and is expanded by the heat treatment. The latter material can be processed in so many ways and is available from so many sources that it is difficult to generalize concerning its properties, however, suitable grades yield results closely similar to those obtainable with vermicultite. It can be used for both seed germination and rooting of cuttings. (Figure 22).

Propagation Under Artificial Light

Another approach to the problem of maintenance of uniform environmental conditions is to use artificial light alone for propagation, thereby eliminating the frequent and violent fluctuations in temperature and humidity which can be encountered when solar radiation is used.

Several years ago, the writer and colleagues at the U. S. Plant Introduction Garden, Glenn Dale, Maryland, developed some equipment for this type

U. OF MASS.

Figure 22. Rooted gardenia cuttings showing influences of sand, fine vermiculite and course vermiculite (left to right) as mediums.

of propagation as a by-product of investigations on the effect of light of varying spectral quality on the rooting responses of cuttings. These frames were well adapted to use in a basement or in a corner of a garage, and could be constructed at very low cost in comparison with a conventional greenhouse of the same capacity. In one instance, a case made from discarded packing box lumber and heavy construction paper gave the operator some excellent results. A number of articles appeared in the popular journals devoted to gardening, in which excellent results were reported with both cuttings and seeds. This device was variously termed by such expressions as "basement greenhouse," "robot greenhouse." Although the expense of electricity would normally prevent growing on of plants beyond the initial stages, a number of people discovered that African-violets thrived under fluorescent lamps. The starting of seeds of perennial plants such as delphiniums and columbines during the hot summers of the Midwest was often found to be much simpler under artificial light in a cool location than in a greenhouse or frame.

Some difficulties were encountered where features of construction or methods of operation upset the balance of conditions within the case. A heavily insulated case, in one instance, failed to permit sufficient heat dissipation with the result that the cuttings were damaged. In another case, a properly constructed case was placed in a position where it was reached by the direct rays of the sun, with the same consequences.

In one series of experiments an opaque shed 10 feet by 36 feet was operated as a propagating house using double 40-watt industrial fluorescent fixtures suspended over the cuttings or seedlings as closely as practicable. (Figure 23). Since that time much longer fluorescent tube lamps have become available and are preferable, since the light levels fall off rapidly near

the ends of the tube.

Using minimum light levels, which, in this instance, were furnished with only two 40-watt fluorescent lamps, excellent seedlings of many plants were grown. The secret of growing good plants under such circumstances is to hold the air temperatures sufficiently low to reduce growth. Unquestionably the use of somewhat higher light intensities increases the certainty of good results, particularly with seedlings. Light intensities of at least six to eight hundred foot candles are desirable for producing good seedlings of most plants. Lower intensities under two hundred foot candles can produce surprisingly good rooting of many types of cuttings if the daylengths are sufficiently long. These are not critical with cuttings; but with some kinds of seedlings, an overly long daylength has undesirable effects. A twelve to sixteen hour day is good for both seedlings and cuttings.

The spectral quality of the light emitted by the lamps is important particularly for seedlings. The various lamps which produce light that is rich in radiation in the red end of the spectrum are more favorable for rooting of certain cuttings than lights which contain a greater proportion in the blue end of the spectrum. In our experiments, the 3500° White lamps produced heavier rooting than daylight lamps. Thus, for rooting, an unbalanced light quality in comparison with daylight was actually preferable.

For seedlings, the relative desirability of the various types of lamps was determined not by the growth rates of the plants, but on their ability to survive and grow well when transplanted to the field. All experiments pointed to the desirability of a relatively well balanced light quality not greatly different from ordinary daylight. The mixture of blue fluorescent lamps with 3500° White lamps produced unusually good results. Daylight tubes used alone were not as good but produced passable results. The spectral balance was much more critical with some plants, such as the tomato, than it was with other species.

The seedlings grown in the propagating house just described were hardened off for field planting by placing the flats in the shade of a building or a tree with full exposure to northern sky for a day or two, followed by an equal period in full sun. Seedlings grown under favorable qualities of artificial light compared very closely with seedlings started the same time in an ordinary greenhouse. A wide variety of flowering and vegetable plants were grown, including both warm and cool season types. Seedlings of both Cymbidium and Cattleya orchids grew well under fluorescent lamps and made about the same growth as in a greenhouse. The level of atmospheric humidity at which the seedlings were grown did not seem to have a particularly great influence on the transplanting quality. Adequate levels of illumination and avoidance of undesirably high temperatures were critically important.

Bottom heat for cuttings was usually provided by thermostatically controlled soil-heating cables. Control of the air temperature was important with seedlings. Ventilation by opening doors may be necessary in small frames. A fine wire gauze screen has been used to allow heat loss without too great a loss of humidity and moisture from the seeding or growing medium.

The doors of the cases which contain cuttings should preferably be kept closed to maintain a humidity not far

below saturation. Sometimes cuttings were left for entire rooting periods of thirty or forty days without watering or other attention.

Time clocks can be used to control the length of day where this is desired. Continuous lighting is satisfactory for cuttings, but undesirable for some kinds of seedlings.

Propagation by artificial light at the present stage of development offers some very attractive possibilities to the amateur gardener, because the operation can be made very nearly automatic. It is the belief of the writer that well designed equipment can equal the performance of an expensive propagating greenhouse. The rooting will be even more rapid under artificial light in some instances because of the more complete control of conditions. The investment can be small and the equipment can be installed in a small space. A case with four tiers, one above the other, was operated with success in one experiment. Relatively little publicity has been given to the method, in the belief that continued improvement in fluorescent lighting would inevitably enlarge the possibilities and eventually bring it into common use. Almost all of the experiences of amateur gardeners who have tried it have been favorable.

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Figure 23. Packing shed, an underground structure, used for propagation with artificial light exclusively.

TAYLOR

Softwood Cuttings

James S. Wells[1]

The propagation of a wide variety of plant materials from softwood summer cuttings is now a comparatively simple matter for the keen amateur, and it can afford him endless interest with the minimum of attention and control. The writer uses the word "now" advisedly, because it is only within the last year or so that a method of propagating softwood cuttings has been devised, that which does not require constant attention and a considerable degree of horticultural skill.

Before considering this method in detail, one should make certain that he clearly understand just what a softwood cutting is and how and when it should be made. A softwood cutting is one that is made from current growth, usually soft growing tips, produced on the plant immediately after flowering.

Inasmuch as the correct time to prune most flowering shrubs is soon after the current crop of flowers is spent, the resulting soft growths can be salvaged and made into excellent softwood cuttings. Almost all flowering shrubs can be propagated from this type of material, and if the cuttings are handled properly, rooting is rapid and vigorous. Generally speaking, most cuttings of this kind are taken from the stock plants from May onwards. They should be cut into lengths of from four to six inches, with a terminal shoot and at least two nodes beneath on each cutting. The leaves are removed from the bottom node, and the cutting trimmed close to this node. Such a cutting may have two to four leaves plus the central growing shoot. In some instances, if this central shoot is extremely soft and inclined to wilt, the soft tip may be cut out, leaving the cutting with two sets of leaves and a third node beneath. So much then for the type of cutting.

Most gardeners clearly understand the problems involved in the successful rooting of softwood cuttings of this kind. They know that a cutting cannot root if the plant material wilts after removal from the stock plant. They also know it is essential that the cuttings remain turgid and do not wilt if they are to root rapidly and successfully. The use of a greenhouse or frame is usually advised, in order that cuttings can be maintained in a closely controlled atmosphere, sprayed with water, and generally protected from the variations of summer's heat and wind.

These methods are tried and proven and it is known that they work, but,—and here is the snag—it requires constant attention for optimum conditions to be maintained in a greenhouse or frame, and this kind of attention, the amateur cannot always give. The frame has to be aired early in the morning and sprayed down. As the day warms up, the frame must be sprayed again and closed down, and perhaps shading rolled over the sash. At mid-day, the cuttings should be sprayed once more, and if the afternoon remains hot, two and perhaps three additional sprayings from a fine nozzle have to be given. How many of the average home gardeners can afford the time to carry out such procedures?

[1]D. Hill Nursery Company, Dundee, Illinois.

Well, happily there is an answer. And although at first sight it may seem a strange one, it is in fact completely logical. Moreover, it works, which, after all, is the only factor of concern. It is the propagation of cuttings through the heat of the summer months right out in the open, with no protection whatsoever from sun and only slight protection from wind, but with a constant mist of fine water being applied at all times throughout the day. This fine mist keeps all parts of the cuttings coated with water, which is sufficient to keep the cuttings in a healthy and completely turgid condition without any other protection. By using the full power of the sun, cuttings set out in this way root more rapidly and with a minimum of attention. With this system, apart from making and inserting the cuttings into a properly constructed propagating frame, no more attention is needed throughout the day other than to turn on the water early in the morning and shut it off after sundown. In the height of summer, the water can be left on with advantage night and day. The writer has had a fog line running for three weeks continuously on a wide variety of cuttings, all of which rooted rapidly under these conditions. It is therefore quite possible for the amateur to make a batch of cuttings, say in early June, or July, set them out and go off for a two week vacation returning to find a strong clean batch of healthy cuttings just getting ready to root. At first sight this may sound impossible, but before you become too sceptical it should be stated that this system is now being adapted and tried, with great success in many commercial nurseries. It is a system that has been tried and found to be highly successful, no matter what the size or scope of the operations.

Now consider just how such a propagating unit of this development should be set up in your garden and used. First, you must abandon all your preconceived ideas of what is the best way to root cuttings. You are out to use to the fullest extent the maximum available energy from the sun. You will need a site in full sun, without any shade or protection whatsoever. You next will need a box about four feet square, with sides six to nine inches high, and beneath this you need to place a layer of clinker or coarse drainage material, some six to nine inches in depth. This base drainage is important, because all surplus water must be able to drain off. Stagnant water, of course, can be fatal. If the natural drainage of the land is poor, such as on a heavy clay, then build up on top with the drainage layer, and place the box on top of this. Fill this box with your rooting medium. For most types of plants, plain, rather coarse plaster or concrete sand will be best, but for certain types of plants, such as azaleas, Pieris, and similar peat loving types, a mixture of half acid type peat moss and half plaster or concrete sand should be used. Fill the box to within an inch of the top and gently firm with a board.

A half inch water pipe should then be inserted under the board and brought up in the center of the box to a height of eighteen inches above the top of the box. To the top of this pipe should be fixed a small jet which gives a very fine mist. Most of the jets used in domestic oil burners are excellent, putting out about one and a half gallons of water per hour at a pressure of sixty pounds per square inch. If you wish to use the best, however, special jets are made to provide a wide angle mist, with not more than 1.6 gallons per

hour at the same pressure. The one that the writer has used in commercial work is the Monarch H261 3.00. This jet is tested at twenty-five pounds per square inch, which is the minimum permissible water pressure. At forty pounds pressure, which is normal for most domestic suppliers, it works well. One jet fixed as described above should cover all parts of the four foot square box. The pipe can be terminated outside the box with an ordinary hose fitting and the water brought to the propagating box simply by connecting the garden hose to this coupling, or a permanent pipe connection can be made. These small jets are each provided with a fine mesh screen behind the jet which keeps the orifice clear.

The sides of the box should then be protected with some form of windbreak to ensure that the mist comes out evenly and covers all parts of the box. A simple burlap screen, plastic, or in fact anything that will just break the wind, is all that is required. Remember, however, that this screen should not cast a shadow on the actual propagating space. The use of the full power of the sun is essential. Set the screen back a little to expose the bench fully at all times. With this construction completed, cuttings can now be received. Under these conditions of constant mist, both larger and softer cuttings can be used, without being affected by water loss. In fact, they remain fully turgid, because all parts of the plant are continuously covered with a film of water. Quite large cuttings of climbing roses, *Ilex opaca* and *I. crenata* and also azaleas, can be taken. Pieces ten to twelve inches in length, with a group of side branches, can be inserted and will take root.

For most cuttings under these conditions, hormones are helpful. Most of the softwood cuttings with which you will probably be concerned will benefit by treatment with Hormodin No. 1 or 2, and in rare cases, No. 3. Cuttings should be removed from the stock plants either early in the morning or late in the evening. Be sure that the mother plants are well supplied with water so that the cuttings themselves are fully turgid when they are removed. The cuttings should be made as described, treated with hormones, and immediately inserted in the fog box. The time required taking, preparing, and inserting the cuttings, should be a matter of only a few minutes, never more than a quarter of an hour. If softwood cuttings have to be kept for longer periods, such as, for instance, bringing cutting material from the garden of a friend, remove the cuttings early in the morning, and immediately wrap them in moist newspaper. Keep the cuttings moist and cool, well damped down, transport them as rapidly as possible, prepare, and insert into your propagating unit. If carefully handled in this way, cuttings can be held over for a day or longer if some distance has to be traveled. But the ideal is to select, prepare, and insert the cuttings within a few minutes. Once cuttings of any kind are in the fog box, the mist *must* run continuously from early morning till late evening. If you plan to be away for a few days, or a week or two, it is better to leave the mist on to run day and night. If the cuttings are in good condition, it will not hurt them.

The list of plants that have been successfully propagated in this way is too long for publication here, but it includes some of the more important staple garden shrubs. *Acer palmatum,* Thuja (oriental and American), azalea, forsythia, hydrangea, Ilex (Japanese,

American, and English); Jasminum, Juniperus, Lonicera, magnolia, *Pieris,* rhododendron, Taxus, weigelia, and a host of similar shrubs, have responded well to propagation in this technique.

When the cuttings have rooted, it is best to reduce the water and allow them to harden off naturally, but without disturbing them in any way. It is wise, therefore, to insert a complete set of cuttings to fill the box as rapidly as possible so that they all more or less root at the same time. As the water is reduced, light shading can be applied to protect the young plants from the direct rays of the sun. Under these more normal conditions the cuttings will rapidly harden off and come to a proper condition to enter the winter. Once a few sharp frosts have been experienced, the cuttings will be completely dormant, and many will be dropping their leaves. This is the time to clean up the bed and place round it a small hand frame with a top sash to protect the young plants through the winter. Keep full air on the rooted cuttings, and keep them hard, but by the proper use of the frame, reduce the normal and sometimes violent fluctuation between extremes of heat and cold which can cause untold damage to young plants of this kind.

Early the following spring, just as soon as the ground is fit to work, the rooted cuttings can be carefully lifted out and planted. The earlier this is done the better, for most plants prefer to be moved and take a new hold on the ground when the soil temperature is cool—not in the hot and unkind weather of late May and June.

As stated earlier, this method is new but it is not untried. Dr. Fairchild was one of the first to use a fog box in his garden in Florida. Commercial growers everywhere are beginning to apply similar methods to their production problems. While at first sight it might appear to be a "lazy mans" type of gardening, it is in fact a logical answer to the problems posed by the orthodox methods described earlier. There is no reason why you should not be in "full production" this summer.

Conifers By Cuttings

WILLIAM L. DORAN[2]

Woody plants have been vegetatively propagated by cuttings, grafting, budding, or layering for more than two thousand years. The first to be so multiplied were probably those individual plants that bore superior edible fruit. Later, probably ornamental woody plants received attention and, more recently, forest trees for economical purposes.

This paper is concerned mostly with conifers grown for ornamental plantings, for the improvement of grounds about the home. Many recognized varieties of such conifers may be vegetatively propagated by stem cuttings made from new shoots taken in late summer after the growth of the current season has been completed. Many may be taken in fall and winter or early spring before growth begins again. Probably the poorest time to take cuttings of most kinds of conifers is in late spring or early summer while they are still making new growth or before such new growth has become at all mature.

Stem cuttings of conifers, as made by the writer, usually consist of the most recent year's growth or the growth of the current year, the basal cut being made at the base of that growth. Cuttings are sometimes made so as to include wood two or three years old at the base, and, of course, the larger the cutting when made, the larger the rooted cutting, if it roots. Cuttings made from younger wood usually root more rapidly or in larger percentages than those made from older wood. This is true with cuttings of hemlock, as a good example.

Cuttings of several species of trees are known to root more readily if taken from young rather than from old trees —trees grown from seed in both cases. This is not necessarily true if cuttings are obtained from a tree which, itself, grew from a rooted cutting, as are many recognized varieties of ornamental conifers. But youthfulness is a factor and, other factors being equal, it is well to take cuttings from a tree as early in the life of that tree as its desirable qualities become evident.

Moreover, cuttings from some trees can be rooted with less difficulty than cuttings from some other trees, even though all are of the same species and the same age. This is referred to as clonal difference in ability of cuttings to root. It may be better practice, therefore, to take cuttings from several individual trees within a species rather than from one tree unless the particular tree is an especially desirable one or one which it is known can be grown successfully from cuttings.

The rooting of cuttings of many species of woody plants is improved by their treatment with a root-inducing substance, such as indolebutyric acid. When mention is made of the treatment of cuttings, or of treated cuttings, the reference in this paper is to the use of indolebutyric acid. It may be noted at this point that such treatments are essential or important for cuttings of some species, unnecessary with others, and ineffective with still others.

Cuttings may be treated bv immersing their lower lower ends for some

[1] *Massachusetts Agricultural Experiment Station Contribution No. 923.*

[2]Research Professor of Botany, University of Massachusetts, Amherst, Massachusetts.

hours in water-solutions of indolebutyric acid or other growth-substance, but powder-dip treatments are simpler.

Powder-dip treatments are applied soon after cuttings are made. The cuttings are loosely bunched, and their basal ends are dipped first in water and then in powders, such as Hormodin No. 1, No. 2, or No. 3. These contain indolebutyric acid in different percentages; Hormodin No. 1, being the least concentrated, and No. 3, the most concentrated. These materials are obtainable from horticultural supply houses together with recommendations as to their preferred usage. For species for which no recommendation is made, Hormodin No. 2 or No. 3 should be tried.

Immediately after treatment, the cuttings are planted in the rooting medium, usually sand or a mixture of two parts sand and one part peat. Some sandy soils may be similarly used, but sandy soil is a vague term and sand or a sand-peat mixture is preferable.

The rooting medium, in flats, shallow boxes, beds or benches with some drainage below, should be moist when cuttings are inserted. Straight lines or grooves, one to two inches deep, depending on length of cuttings, are cut about two inches apart into the surface of the rooting medium. The distance betwee rows depends upon the spread of the cuttings. The ends of the cuttings are inserted in these grooves to the required depth, with the cuttings approximately erect. The rooting medium is then pressed firmly about the cuttings and well watered.

Now follows a period of weeks or even months during which the still unrooted cuttings must be protected against the drying out of the rooting medium and, no less important, the drying out of the air around them. In a greenhouse, this can be accomplished by light shading and regular sprinkling of benches and walks. The maintenance of a sufficiently high relative humidity and enough light is somewhat difficult outside the greenhouse. In small scale operations, as in the home, cuttings have been covered with inverted glass jars, a Wardian case or glass tank with the top covered by a pane of glass. Attention must be given to occasional ventilation and, of course, reasonable watering. The cuttings should be in a well lighted room but not in direct sunlight.

A method recently described by Lipp (discussed in the last paper in this issue of the Magazine) for rooting cuttings without a greenhouse is of interest. According to Taloumis (*Horticulture* 31(9):369, 376, 380. 1953.), Lipp thus rooted cuttings of yews and other conifers.

In the work of some investigators (Grace and Farrar), cuttings of Norway spruce placed in outdoor frames in November rooted well by the following summer, but how successful this method would be with some other species is uncertain. It would probably depend upon the severity of the winter, the species, and the care given the cuttings.

Attention is called to the relative ease or difficulty of rooting, the time of year at which cuttings were taken in my experiences, and the importance or unimportance of treatment with a root-inducing substance. These are notable factors under any circumstances.

American arbor-vitae is not difficult to propagate by cuttings taken in fall or winter. Treatment may improve or hasten rooting. In the work of some propagators, August cuttings have been reported to root slowly but well in a

cold frame.

Most species and varieties of yew are not difficult to propagate by cuttings taken in late summer, fall or winter. Cuttings may consist of wood one to three years old, but those made from wood not more than one year old are often easier to keep alive. Treatment may hasten rooting.

Cuttings of eastern red cedar, *Juniperus virginiana,* root in higher percentages when taken in December. Rooting of cuttings of some of the varieties of this species is improved by treatment.

Pfitzer's juniper can be propagated by cuttings taken from August to midwinter. Treatment improves rooting.

Cuttings of creeping juniper, *Juniperus horizontalis,* taken in fall and winter, usually root well without treatment.

Cuttings of Colorado spruce, *Picea pungens,* taken in late winter and treated with a root-inducing substance, root well. Cuttings of Norway spruce and its varieties, taken from November through February, root fairly readily without treatment.

Untreated cuttings of Colorado fir, *Abies concolor,* root well when taken in late winter. Rooting of cuttings of some other firs is improved by treatment.

Treatment is beneficial in rooting cuttings of Hinoki cypress, *Chamaecyparis obtusa.* Treated cuttings of this species root equally well when taken in October, November, and December. Sawara cypress, *C. pisifera,* is readily propagated by cuttings taken in these months although they often root in larger percentages if treated with a root-inducing substance.

Eastern hemlock is not difficult to propagate by cuttings, although cuttings from some trees of hemlock root much more readily than do those from others. Treatment with indolebutyric acid is helpful, often necessary. Treated cuttings have rooted successfully taken from August through January. Carolina hemlock may be propagated by cuttings taken in fall and treated.

Best results with white pine are obtained with cuttings taken in late winter and treated. Pines are rather difficult to propagate by cuttings and the amateur is not encouraged to do much with this species.

Ginkgo, although not a true conifer, is easy to propagate by untreated cuttings taken in June. Cuttings should be taken from staminate or male trees, for the fruits on the female trees have a very disagreeable odor.

Rooted cuttings of conifers should be planted in a protected location, and there allowed to remain at least during the first year after rooting. Rooted cuttings are more susceptible to injury by cold or dryness in their early years than they are thereafter.

It is not to be supposed that beginners will immediately succeed in rooting large percentages of conifer cuttings of some species and varieties, or that the nursery business will be adversely affected. But as a hobby, with patience and care, and increasing experience, the field can be of great interest to the serious plantsman.

Japanese Maples By Inarching

Floyd F. Smith[1]

The Japanese maple, *Acer palmatum,* is propagated commercially by budding or grafting dormant wood of desired varieties to potted seedlings forced into active growth during the winter in the greenhouse. A grafting case is used to insure uniform temperature and humidity until stock and scion unite. Often, however, the results are disappointing. Moreover, gardeners who lack greenhouse facilities are unable to propagate plants from a desired tree by this method.

For nearly thirty years the writer has tried various methods of propagating Japanese maples, including budding and side grafting in his greenhouse and out of doors, and bottle grafts in the field. As a result, what appears most practical for the amateur, is a method of approach grafting, or inarching. It can be performed in any garden on either small or large trees. The method may also have commercial possibilities because it is possible to graft at least twenty plants per hour and the plants require a minimum of care after grafting. In most years nearly all the grafts made have been successful.

Two-year-old seedlings for understocks are potted in the fall or early spring and plunged in the soil under shade of lath or shrubs. They are kept in active growth by watering and fertilizing until time for grafting in July or August. Weak side branches are trimmed from those with stems three-sixteenths to one-fourth an inch in diameter, and the plants are depotted. A thin slice of bark two inches long is cut from the side of a smooth section of stem near the soil level. The scion wood is selected from vigorous current season's shoots with long internodes to permit the grafting of several seedlings on the same shoot. A similar slice of bark is cut near the base of the shoot, preferably above the first node, to leave two buds on the parent plant for next year's shoots.

The cut surfaces of the seedling and scion are brought together and bound

[1]Bear Garden Nursery, Ashton, Maryland.

HAWLEY

Figure 24. Four seedling Japanese maples grafted onto one scion. (The scion is cut from the parent tree in this illustration to present a clearer view of successive grafts on one scion.)

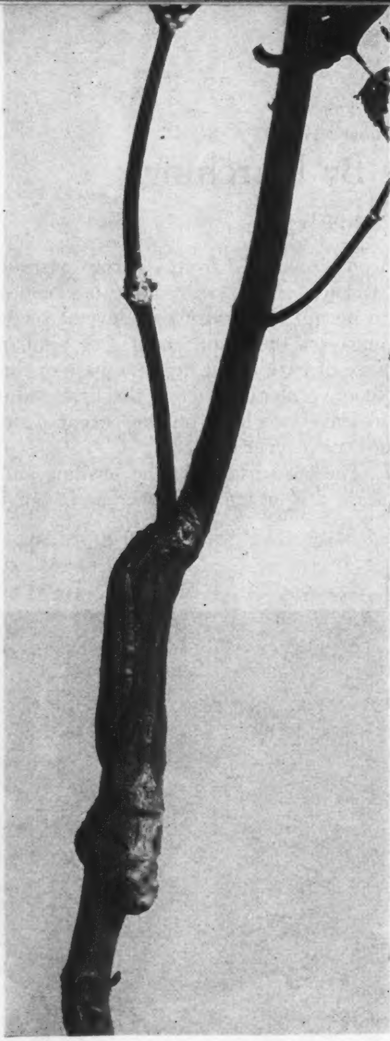

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Figure 25. Grafted Japanese maple showing union of stock and scion two years after inarching.

firmly in place by wrapping with a strip of heavy muslin, one-fourth inch wide and six inches long, that has been dipped in melted beeswax. The beeswax gives added strength to the strip so that the stock and scion may be forceably drawn into close contact, and its adhesiveness hold the wrapped strip in place without tying until the graft union is completed.

Successive grafts with other seedlings are made on the more distal internodes of the same shoot of scion wood. (Figure 24). Other strong shoots on the same scion tree make it possible to obtain ten to fifty grafted seedlings from one source plant.

Grafts from a small source tree are obtained by bending over to a horizontal position and tying to a stake. After the seedlings have been grafted to this plant, a hole three to four inches deep is dug in the soil. The seedling roots, each in a soil ball, are then arranged in the depression and covered with the loose soil. The seedlings are later mulched with straw or leaves for winter protection.

Grafts from a large tree are obtained by nailing a shallow metal container, such as a section of lard can, with drainage holes to a stake at the desired height and partially filled with soil. A branch is then brought in position and tied so that current season shoots can be grafted to seedlings that are planted in the container. The seedlings in the cans are severed from the sciön tree after leaf fall in November and heeled in soil in a cold frame covered to prevent freezing.

In the spring, as the buds swell, each seedling is cut from the parent tree, and the top and muslin band are removed. The grafted plants are set in a bed eight to ten inches apart with the graft union close to or below the soil surface. Young sprouts from below the graft are removed as they appear.

The more vigorous shoot from the two buds on the scion is selected for a main stem of the young tree. (Figure 25). The plants are shaded for the first summer, protected with leaves or pine branches during the following winter, and transplanted to the nursery row before growth starts in the spring.

Flowering Bulbs

S. L. Emsweller[1]

The term "bulb," as used by the botanist, refers to a thickened, fleshy bud, usually growing underground. Such well known plants as the onion, lily, hyacinth, tulip, and narcissus, are bulbous plants. To the average gardener, however, a bulb may be any plant structure useful as a storage organ to maintain a plant over its dormant period, spent either in the soil or in a tray in a bulb shed. According to this latter and popular interpretation, the gladiolus, dahlia, and the Dutch iris, as well as many other plants, may be classified as bulbous plants.

Since named varieties of flowering bulbous plants do not come true from seed, they must be propagated asexually, that is, by formation of new bulbs or bulblets on some part of the plant or by natural splitting of the old bulb. Fortunately, nearly all bulbous plants increase themselves normally in a variety of ways. In most instances, the old bulb forms a small division or split each year. Generally, lily plants also form small bulblets at the underground nodes of the flowering stem, and a few species form aerial bulbils in the axils of the stem leaves.

The natural methods of propagation of most bulbs can be stimulated in a number of ways. Usually these artificial methods increase the quantities and reduce the period required for formation of new bulbs. This paper has been prepared to explain these techniques as applied to some of these bulbous plants, accepted in the popular classification.

[1]Head, Division of Ornamental-Plant Crops and Diseases, Plant Industry Station, Beltsville, Maryland.

Lilies

If the growing point of the lily stem is removed early in the growing season, some of the dormant buds at the base of the stem are usually stimulated to grow, and the old bulb splits into several divisions. This condition prevails following a late killing frost in the spring. It is essentially the same result as occurs when plants are pinched back to make them branch.

The underground stem bulblets of lilies can be increased in size and number in the following manner. Soon after the flowers fade, carefully remove the soil above the bulb, with as little damage to the stem roots as possible. Cut the stem directly above the bulb and replant it immediately, setting it an inch or so deeper than it was when attached to the bulb. Such transplanted stems continue to grow through the season and the next year many large stem bulblets can be harvested. The old mother bulb is reduced in size, but not permanently injured.

There are many lilies, such as *Lilium candidum, L. hollandicum, L. longiflorum,* and others, that form many stem bulblets if the stem is heeled in after the bulb has been harvested. This is done by opening a shallow trench, sloping one side at about a forty-five degree angle and placing the stem base down in the trench. The stem is then covered with soil and within a few months many stem bulblets are formed. (Figure 26, Top, left). Such stem bulblets may be removed and planted about two inches deep.

Some lily species, notably *L. longi-*

florum, can be increased also by means of leaf cuttings. Such cuttings should be made while the stem and leaves are green, usually shortly after the plant has flowered. Each cutting should have a small part of the stem attached. The cuttings may be placed in coarse sand so that the base of the leaf and piece of stem are just covered. The sand should be kept moist. Within four to six weeks small bulblets form at the base of the leaf. When the cutting is well rooted it may be potted or planted outdoors, depending on the season of the year. Leaf cuttings are best made during cool weather.

A very efficient way of propagating all species of lilies is by the method commonly called scaling. All lily bulbs are composed of scales attached at the base of the bulb. There are two general sizes of scales: the most common type, like that of *L. longiflorum,* and a smaller one, such as the scales of *L. superbum* or *L. pardalinum.* When a lily is to be propagated by scaling, the scales are removed by pulling them from the base of the bulb. They should then be dusted in a fungicide, such as Fermate or Arasan, and then planted about one to one and one-half inches deep in moist soil. The scaling should be done during warm weather when the soil temperature is high, and the scales should not be permitted to dry out. Within three to six weeks small bulblets and roots form at the basal end of the scales. (Figure 26, Top, right). If the operation is done by the middle of August, many lily scales will produce bulblets and some foliage during the fall. When the foliage has been killed by frost, an additional two to three inches of soil should be added so that the young bulblets are three to four inches deep.

Since each lily scale usually produces three to five small bulblets, one can quickly obtain a large number of small plants by scaling. Some species, such as *L. longiflorum,* can be flowered the first year from scales. Other species may not flower for three years. Species that grow rapidly can be transferred to their permanent location the first year after scaling.

Additional plants of some species, such as *L. sulphureum* and *L. tigrinum,* the common tiger lily, can be developed from the aerial bulbils produced in the axils of the stem leaves. (Figure 27).

Tulips and Daffodils

The propagation of tulips and daffodils is entirely by natural splitting of the old bulb. When daffodil and tulip bulbs reach a certain size they produce small off-sets or splits and these may be removed and planted in rows where they remain until they reach flowering size. The rapidity with which varieties increase varies greatly and may be the deciding factor whether a new seedling is named and put into commerce. Other bulbs that behave in a similar manner are Dutch iris, some species of Muscari, of Nerine, Amaryllis, and many others. (Figure 26, Bottom, left).

The natural splitting of both tulips and daffodils can be increased by shallow planting. This is especially true of tulips. When they are planted at various depths, the degree of splitting is usually greatest at three inches, greatly reduced at six inches, and almost eliminated at nine inches. Similar results can be obtained with daffodils. These results indicate that deep planting is advisable for both tulips and daffodils, especially if one wants to keep the plants in place for several years. If, however, it is desirable to increase rare varieties, shallow plant-

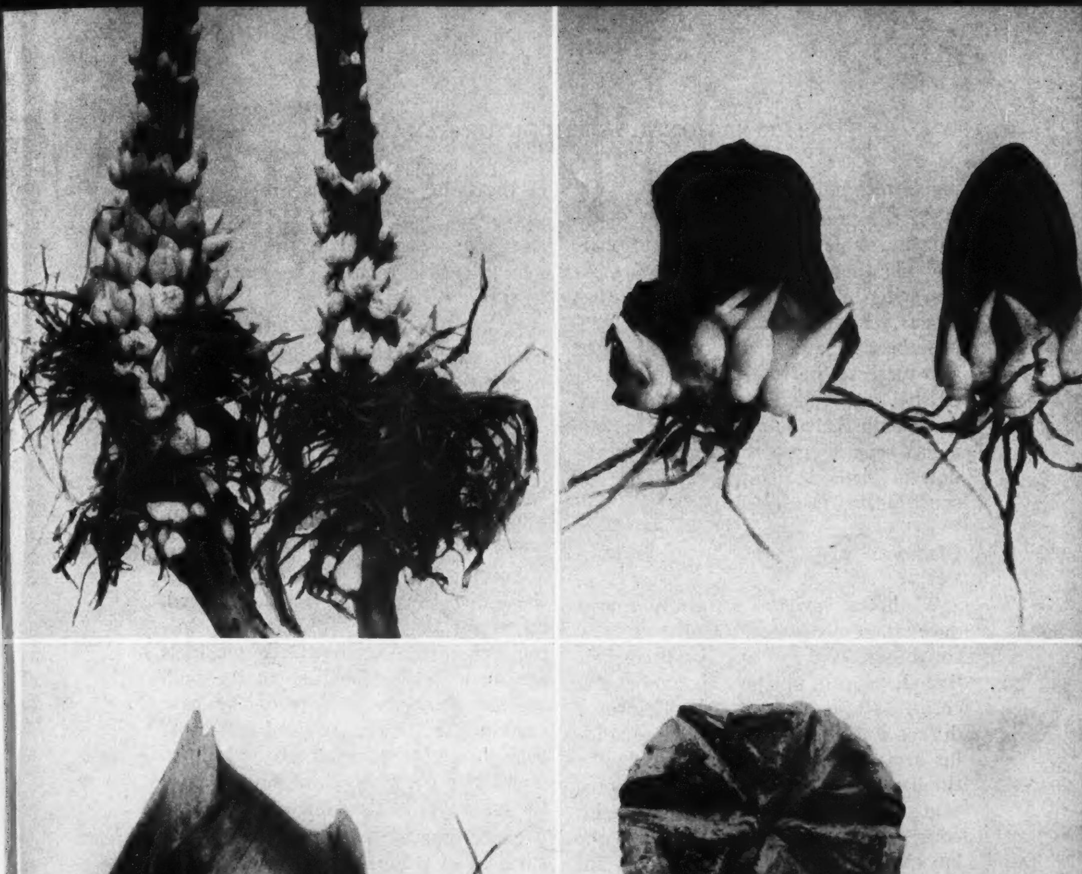

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Figure 26. Top: Left, Lilium hollandicum stems heeled in on July 7 and photographed August 8 showing formation of bulblets along the stems. Right, detached scales of Lilium leucanthum showing newly developed bulblets. Bottom: Left, Dutch iris bulbs showing natural splitting of old bulb. Right, scored hyacinth bulbs, lower bulb shows formation of new bulblets.

ing is recommended.

At the present there are not many data available as to the effect of shallow planting on propagation of most flowering bulbs. It appears likely that crocus, Ixias, Sparaxis, Watsonias, Montbretias, and many others, might also increase more rapidly when planted shallow. It is not known just why some bulbs behave in this manner, but it has been suggested that better aeration in shallow planting may be the contributing factor.

Gladiolus

Gladiolus varieties naturally reproduce themselves by forming a new corm each year and also small cormels that develop in clusters about the new corm. The number of cormels formed differs with the variety. When gladiolus are planted a few inches deep, the small cormels are produced in profusion; as the depth of planting increases, cormel production is decreased. If one buys expensive new varieties, it is advisable to plant shallow in order to obtain a good increase of cormels. Such shallow planting usually requires staking, but it does speed up production.

Gladiolus may also be propagated by cutting up the corm, leaving an eye on each piece. This procedure is somewhat hazardous, however, since the cut surface exposes the tissue to fungus spores and it is difficult to prevent infection and rotting. Since natural methods are more efficient and less liable to result in loss from rotting, cutting corms is not advisable.

Hyacinths

There are at least two bulbous plants, hyacinths and scillas, that may be propagated by scoring or scooping the base of the bulb. Hyacinths are regularly propagated by these methods, but scooping is considered preferable by many because it results in more bulblets.

Scooping may be done with a curved blade scalpel or a teaspoon that has had its edge sharpened. If the spoon or scalpel is not sharp, it will be difficult to cut through the tough dry base of the bulb. It is essential that the cut be made so that all the basal plate is removed and all cut surfaces of the bulb scales are exposed.

Scoring differs from scooping in that the entire basal plate is not removed, but is cut diagonally. (Figure 26, Bottom, right). Usually three channels are made across the base of the bulb so that six equal sectors of the base remain intact. The grooved cuts must pass through the center of the bulb to reach the growing point and expose the cut bases of the scales.

Since fungus rots may attack the cut surfaces of scooped or scored hyacinth bulbs, it is important to take precaution to keep the cutting tool sterile. This can be done by using two cutting tools, standing one in alcohol, or some good disinfectant, while the other is in use. It is unwise to use a cutting tool immediately after removal from a strong disinfectant since injury to the bulb tissue may result.

As soon as the bulbs have been cut, they should be placed in dry sand at a high temperature, ninety to a hundred degrees. The bulb should be covered at least one inch deep and allowed to remain until the cut surfaces have formed calluses. This usually occurs in about two weeks. As soon as the bulbs are well callused, they should be placed in shallow flats or trays to be incubated. The bulbs should be well

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Figure 27. Lilium sulphureum showing increased size of aerial bulbils on stem from which the flowers were removed at time of flowering.

spaced in a tray so that aeration is good and the bulbs do not touch one another.

During the incubation period the temperature should range from seventy to ninety degrees. Such temperature speeds up the formation of small bulblets at the cut surface. During incubation the bulbs must not be permitted to dry out too much. If the natural humidity of the air is too low an open pan of water placed near the tray will be of some help. The incubation period lasts until the small bulblets produce some root growth. Since this may take as long as three months from date of treatment, it is advisable to scoop or score the bulbs as early as possible.

When roots are formed on the new bulblets, the old bulb should be planted out. The scored or scooped bulbs should be set about two to three inches deep. The next year the bulblets should produce considerable top growth. It is generally advisable to dig the bulbs the first year and space them a few inches apart. By this time the mother bulbs probably will have almost disappeared, having served as food for the new bulbs. Some few will

flower the second year, but large bulbs will usually not be produced in less than three to four years.

Hyacinths can be propagated also by means of detached scales, which is simply a modification of the scooping or scoring method. The old bulb is broken up and the scales, with a piece of the basal plate attached, can be placed down in sand. They behave like lily scales and soon form small bulblets and roots.

It is also possible to propagate hyacinths from leaf cuttings. The leat can be cut near the top of the old bulb and then cut into two or three pieces. Each piece should be placed in sand with the lower end of the leaf two or three inches below the surface. Hyacinth leaf cuttings should be made just as soon as the flower stalk is in full bloom, although cuttings can be made as long as the leaves are green. The formation of bulblets will be speeded up if some bottom heat is applied. The leaf cuttings should not be allowed to dry out, and if necessary to increase humidity they should be covered with a glass jar. The bulblets start to form in two to four weeks and eventually roots are formed. As soon as this stage has been reached, the cuttings should be planted in soil.

Several other flowering bulbs can be propagated from leaf cuttings and further research would probably reveal many more. *Lachenalia unicolor, Muscari szovitzianum,* the small grape hyacinth, and Haemanthus, the blood lily, will form small bulblets on leaf cuttings. The leaves of Lachenalia can be cut into several pieces and each one, just like hyacinth leaves, will form bulblets at the basal end. (Figure 28). Both the grape hyacinth and the blood lily form many small bulblets at the base of the leaves. In all instances leaf cuttings should be made when the leaves are green and the cuttings should not be allowed to dry out.

Some species of Scilla and some Muscari can be propagated by scoring the basal plate of the bulb. The increase, however, is not so great as with hyacinths. The basal plate should be cut with at least two diagonal

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Figure 28. Leaf cutting of Lachenalia. Bulbils formed on top section of a leaf (top); middle section of a leaf (center); lower section of entire leaf (bottom).

strokes of the knife, cutting deeply enough to enter the growing point and through the bases of the scales. It is advisable to dip the cut bulbs in a fungicide dust such as Arasan. The bulbs should be held at a fairly high temperature, eighty to ninety degrees, for a few weeks until the cut surfaces have callused. As soon as callusing is complete, the bulbs can be planted out.

Dahlias

Dahlias normally propagate by formation of a cluster of fleshy roots at the base of the flowering stems. These root clusters are usually stored during the winter and are not divided until planting time. Each fleshy root will porduce one to several buds (eyes) on the end attached to last year's flowering stem. When the roots are to be set in the garden, the cluster should be broken up by cutting each root from the old stem, being careful not to damage the buds that usually will have started growth by this time. When several buds are present, many gardeners remove all but the strongest, unless they want a bushy plant with several stems.

Dahlias can be propagated also by means of cuttings. This method is used for new and rare varieties. It requires that the old clump be forced into growth a few months before planting time. As the young shoots appear, sections can be removed, rooted in sand, and then potted for later transplanting outdoors. Several series of such cuttings can be taken in one season. If the cuttings are made leaving a pair of leaves on the stem of the parent plant more shoots will be formed.

Amaryllis

Amaryllis normally propagate by forming small offset bulbs around the mother bulb. These may be left with the mother bulb for a year or so or removed when the plant is dormant. In addition, Amaryllis bulbs can be propagated also by the process commonly known as reaming. The reaming is done by cutting out and removing the center of the base of the bulb to a depth of not more than an inch, being sure to leave a fringe of roots around the cavity. The bulb should then be dusted in a fungicide and repotted. By the end of the first season the bulb may be expected to produce many offsets. When these offset bulbs are two years old they may be removed and planted.

Summary

There are many flowering bulbs that have not received much attention from plant propagators. Since many of these are true bulbs with fleshy scales, it is probable that they would form bulblets on detached scales. In some instances, such plants may develop bulblets on leaf cuttings and almost surely on leaf cuttings with a bit of the basal plate attached.

The greatest hazard in propagating from either leaf or basal plate cuttings is fungus diseases that may attack the cut surfaces. If such surfaces can be protected until a good callus is formed the danger of rotting is reduced to a minimum. Fortunately, there are now available a number of good fungicides, such as Arasan and Fermate. Freshly made leaf or basal plate cuttings should be dusted with these protectants before they are placed in the rooting medium.

Rose Propagation

Niels J. Hansen[1]

Home propagation of roses can provide the amateur with pleasure and pride as well as with varieties difficult or impossible to buy. It is about the only method in which he can obtain many species and varieties no longer grown commercially. Usually, any rose not advertised extensively, gradually loses its popularity. Too few sales will cause it to be dropped from the catalogs, and after a few years of obscurity, it will be lost to the trade. In gardens here and there, however, it may do exceptionally well, and the owner may grow so fond of it, that he cannot think of parting with it, though it is no longer stylish. It may also, from time to time, produce a flower which will carry away the honors at a nearby or distant show. When these happen, it is bound to cause some rosarian to want the variety for his own garden. There being no known source of supply, it is necessary that he be able to reproduce it at home.

Most of us carry fond memories of a beautiful rose which we knew long ago. Through the years it has grown in our minds to be much more beautiful and much more desirable than it probably was. There is no way of buying it now, but so and so has a plant, and he is willing to spare a little wood for propagation if you know how to use it. Some people have a flair for antiques, and any old rose found escaped from cultivation, or growing around abandoned houses, is a "must." In some cases, the whole plant can be dug up and moved, but in others, where digging is not possible, it is necessary to know a bit about various methods of propagation in order to bring home the prize and successfully reproduce it.

Home propagation of patented roses should not be undertaken, because it is just as much against the law to asexually propagate one plant for ones own use as it is to propagate a thousand for sale without obtaining a license first. The writer's paper applies to the non-patented roses the home owner is free to propagate.

Aside from seeds, roses can be propagated by various methods such as grafting, budding, cuttings, layering, and division.

Division

Division is by far the easiest and most certain form of propagation, but unfortunately few types of roses lend themselves to this procedure. Some of the species, and also some of the old varieties growing on their own roots, however, can quite easily be divided. *Alpina, blanda, carolina, damascena, humilis, lucida, nitida, palustris, rugosa,* and *spinosissima* are some of the species that can be propagated by division. Varieties of *R. damascena, gallica, spinosissima* and moss — in general, many of our so-called old-fashioned roses—can also be handled in this manner. Any rose which produces underground stems or suckers can be divided, but, while the method is sure, it is also slow, and it would not be profitable as a commercial venture. In home propagation, the profit motive

[1]President, American Rose Society, Washington, D. C.

does not count—if it did, there would probably be no home propagation. There is no doubt that the home-made plant may be or sometimes is an expensive one.

Dividing a rose bush is simplicity itself. The whole plant can be dug while dormant, and divided into as many parts as it has individual stems with well developed roots. These divisions should be planted as soon as possible in their permanent locations, or if planting cannot be done at once, they should be heeled in temporarily. If a single plant is wanted, it is not necessary to dig the whole clump, but just enough to serve the purpose. It may not always be required, but to speed recovery, it will pay to cut the top of the division back to a size that can easily be suported by the roots.

Layering

Next in line in the matter of certainty, comes layering, which is also a very slow method. Layering is practical with climbers and shrub roses, but need not be confined to them. It does not require any special skill or "luck" for success. In its simplest form, a cane is bent to the ground and a few inches of the cane, at the point of contact, are covered with a small mound of soil. All leaves should be removed from the part of the cane which is to be buried. If the cane is not a supple one, it may be necessary to use pegs to hold it in place. Rooting may take place in a few weeks, but severing of the cane from the mother plant should not take place until the roots are strong enough to support the new plant.

The best time to do the layering is possibly during July or August, but it can be done at almost any time during the year. A layered plant can be moved to a permanent location when dormant, or it may be planted in another spot for the time being and allowed to grow before final placement.

Some varieties of climbing roses, especially those of *R. multiflora* or *R. wichuraiana* parentage, grow readily from tip layers. Tips of nearly full grown canes are pegged down, and in a comparatively short time, numerous roots are found at the point of contact. They may be severed and moved as soon as rooted. With tip layering, no part of the cane useful in the production of next year's flowers is wasted. It is not unusual for *R. multiflora* to tip layer itself without any help.

Cuttings

Cuttings may not give a one hundred per cent stand, but, nevertheless, growing roses from cuttings can be an interesting venture, and many a home gardener gets more pleasure out of a small plant grown from a "slip" than from a larger and much better plant bought from a fine nursery.

Cuttings can be made in summer from growing or green wood, or in winter from dormant wood. Wood of the same season's growth is used in either case. July, August and September are the months when greenwood cuttings can be made with a good chance of success. A few days after a flower has faded, the shoot which carried it is suitable for a cutting provided the wood is of moderate size and firm. A heavy, pithy shoot should not be used, as it has little chance of rooting. The spent flower and eight to ten inches of stem are removed from the mother plant. A clean cut, with a sharp knife, is made just below the lowest leaf. The spent flower is removed within a couple of inches of the

top of the stem. This should leave a stem from six to eight inches long. All leaves except the top one should then be removed, and the cutting is made.

A few square inches of soil should be dug out to the depth of nine to ten inches in a shady spot. The resulting hole should be refilled with a mixture of soil, sand and peat in about equal proportions. The mixture should be firmed down before placing the cutting. The cutting is pushed into the prepared soil so deep that only the leaf and an inch or so of stem remains above ground. Label at once and water. A glass jar with a wide opening should now be placed, bottom up, directly over the cutting and label. The jar will act as a miniature greenhouse, or protector. Unless rooting takes place quickly and heavy shoot growth starts, it is safe to leave the jar in place till the following spring. During winter in cold climates, it should be covered completely with soil. The soil is removed in spring when danger of severe cold weather is past, and as soon as growth is well under way, the jar must be removed. If a shady place is not available, it is necessary to shade the jar with burlap, or other suitable material.

Instead of using a jar, a small or large frame may be built to fit a given size of window sash. It may be necessary to provide drainage for such a frame, depending on its location. But in any case, the frame should be partly filled with prepared soil, as described above, to the depth of ten inches. Instead of prepared soil, sharp sand can be used. The distance from the surface of the medium to the glass should be from six to twelve inches.

Cuttings can be placed a few inches apart in such a frame. The frame may be filled at one time, or cuttings may be added from time to time as they become available. Remember to water the cuttings just inserted, and replace the sash, which must be shaded to keep out strong sunlight. Be sure to label each cutting or groups of the same lot carefully, and in a consistent manner to avoid mixing when the time comes to remove the cuttings.

When using a jar, one watering will usually be sufficient unless the weather is abnormally dry; but in a frame, weekly watering may be required, and if sand is the rooting medium, careful check should be kept of the moisture content. Water should not be overdone—neither should it be neglected. As with the jar, it will be necessary to give the frame protection during winter. Salt hay, leaves, or straw can be piled over the glass. Removal should be done gradually in early spring.

Whether under jars or in frames, the cuttings should not be disturbed until spring when they should be moved to a nursery bed to develop for a year or two before being planted with established roses. To be sure, with care, it is possible to grow them along side larger plants. They may be propagated by the jar method in the very place where they are to grow permanently, but it is much easier to take care of them while small, in a bed by themselves.

Some varieties root with difficulty. In such cases, it may be worth while cutting the stem with a heel. This simply means taking along a sliver from the older wood when removing the cutting from the mother plant. Dipping the cutting in one of the root promoting substances may also help. The heel method is of use with roses which strike roots more readily from older wood. *R. Roxburghii*, for example, grows readily from two year old wood.

Hardwood cuttings or cuttings made from dormant wood can be made any time from November through February and early March, depending on the locality. This method is practical with many climbers, shrubs, and species. It is especially useful with *R. multiflora,* when it is to be used for understock, bank cover, or farm hedge. For such purposes seedlings can be obtained from many sources, but where a definite type of *R. multiflora* is wanted, asexual propagation will produce the exact counterpart.

Hardwood cuttings are made from canes grown during the past summer, or from laterals of the same age. Large, pithy canes and wood injured by cold should be avoided. Slender, well ripened canes or laterals are cut into pieces about eight inches long, tied in small bundles and stored in sand, sandy soil or moist, but not soaking wet, peat moss. They should be covered completely by whatever material is used and placed where the temperature will remain as nearly constant as possible, preferably from thirty-five to forty degrees. Usually the cuttings are stored upside down, but this is a refinement not too important. It is important, however, to have the tops all in one direction to save time when planting. While they need not be stored upside down, they should be planted right side up. All the dormant buds are above the leaf scars, and, if developed, they all point toward the tip of the cane, so it is not too difficult to determine which is top and bottom.

As soon as the soil is workable in the spring, the cuttings should be planted in their permanent places, or where they are to be grown while gaining size. Unless the cuttings have developed roots in storage, they are pushed into the well prepared ground with no more than an inch or so protruding. The soil is firmed around them with a blunt stick, or simply by stepping on the soil close to the cuttings. If roots have developed during storage, which is not unusual, it pays to plant carefully, using a trowel to make a hole large enough to receive the roots without breaking. In mild or moderate sections of the country, the cuttings need not be stored till spring. They can be planted in the desired location immediately after being made. If frost should heave them a little, they should be pushed down and firmed again in early spring.

Several precautions must be taken if the cuttings are desired to provide understocks for budding the following summer. When making the cuttings, all buds except two at the top should be removed. A V-shaped cut is certain to do the work thoroughly, but a smooth cut can also be employed provided it is deep enough to remove the "root" of the bud and wide enough to include the latent buds on either side of the main one. The bud removal is to prevent suckers from developing below the scion after budding has taken place.

Only half of the cutting is planted below the ground level; the other half is covered by hilling soil to the top. If the roses are to be budded in their permanent places, this shallow planting and hilling can be dispensed with, and the cuttings may be planted to the usual depth. But for roses which are to be transplanted later, the shallow planting makes an easier job of budding and transplanting, and incidentally, a better looking plant if it is to be shown off at digging time.

Root cuttings are used but little, yet many species can be propagated thusly Roots are dug during fall or winter

and cut into pieces two to three inches long. They may be stored cool, as with dormant cuttings, or if the weather is suitable, planted at once. The root cuttings should be planted in shallow drills and covered with two to three inches of soil.

Budding

The most interesting method of home propagation and one that is easily mastered, especially through personal observation of the act, is budding. It may seem involved when reading a description of it, but actually, it is a very simple operation, which can be learned in a few minutes.

Budding is a simplified form of grafting in which the smallest possible scion is used, namely, a single axillary bud attached to a very small piece of bark. This bud with its small piece of bark is inserted through a small slit under the bark of the understock in such manner that the cambium layer of the bud comes in intimate contact with the cambium layer of the stock. The scion is tied firmly in place without covering the bud itself. Union takes place in about two weeks if the operation is successful, and the tie can be cut or loosened, three to four weeks after budding.

Understocks for the budding of roses can be grown from seeds or cuttings, either being easily obtained. Several species and varieties are in common use commercially, but for home use *R. multiflora* is probably as good as any. How to make and how to plant the stock cuttings have already been described. If seedlings are to be used rather than cuttings, it is necessary to select small plants with straight tap roots, one-eighth to one-fourth inch in diameter. Seedlings with crooked roots, or with large branched roots near the top, are not suitable and should be discarded. The upper three to four inches of the root should be freed of any small roots which may be present. The main root is then shortened to about eight to ten inches, and the top is cut back in the same proportion.

Great care should be used to make sure that at least three inches of the top of the root are planted above the soil level. This part of the seedling is covered after planting by hilling soil around it, so that only the top of the plant is in the open air. The hilled soil should be left undisturbed until time for budding.

Budding can be done from June through September when the stocks are ready; July and August being possibly the most favorable months for the operation. To be large enough for budding, the stocks should be from three-eights to one-half inch in diameter near the top of the root. It is possible to work with smaller, as well as larger stocks, but the prescribed measurements merely indicate the optimum. They should be in good growing condition to insure easy peeling of the bark when the buds are to be inserted.

The first consideration when the actual budding is to be done, should be the budwood or scions. The wood should be selected in the same manner as that for a greenwood cutting; that is, a lateral which has just finished blooming. Such a lateral may have from three to many leaves, and immediately above each leaf is situated a growth bud, each one a potential scion. In general practice, however, and if budwood is plentiful, only the well developed buds are used. Those low on the stem are often recessed or unde-

veloped while others near the top are too far advanced or immature. For an amateur who wishes to propagate a particular variety of which good bud-wood is scarce, there may not be much to choose from, and it is, therefore, comforting to know that almost any bud, under-developed or far advanced, can produce a plant if the budding is done carefully.

As stated above, a shoot which has just shed its flower is the ideal. On such a stem the prickles fly off when a slight side pressure is applied to them. There are some exceptions to this rule, but they are not too important. After the stem is removed from the plant, the leaves are cut off in such a manner that an inch or so of the leaf stalk is left on the stem to serve as a handle when the bud is inserted. The stem should then be placed in water, or moist peat poss until it is to be used. It should not be allowed to wilt or dry, nor should it be left in water for days. If it is necessary to keep the wood for a prolonged period, it should be packed in moist sphagnum or peat moss and kept as cool as possible. If, however, the budding can take place immediately no precautions, beyond removing the leaves, need to be taken.

The stock is made ready by removing the hilled soil. Any rootlets which may have started in the mound are cut off carefully, and the root is wiped clean with a piece of rag or a clean thumb. The plant is then tapped gently to remove any loose soil that may remain in the closely set branches. Bending or kneeling over the plant, the stock is held firmly in one hand while a T-shaped cut is made through the bark as near the soil line as possible. The horizontal cut at the top is usually made first, but either way will work. The longitudinal slit need not be more than an inch or an inch and a half long. The cuts should not be deeper than the bark. On both sides of the slit, the bark is then parted or lifted gently from the wood with the projection made for the purpose on the budding knife. A budding knife made for the purpose is convenient, but not necessary. If no budding knife is available a letter opener made of ivory or wood can be used. A dull knife blade is also suitable. The stock is now ready to receive the bud.

To prepare the bud, the stem, or bud stick, as it is termed, is held upside down in the hand. The knife, which should have a keen edge, is placed half an inch or so above the bud to be cut. If the stick is pictured right end up, the cut would actually start below the bud. The knife is then drawn, not pushed, under the bark and bud until it emerges about an inch below the bud. The bud with its small piece of shield-shaped bark and a sliver of wood should be held between the thumb and knife blade when the cut is completed, and from this position it can be started into the T-cut in the stock without further handling. It may be necessary to complete the seating of the bud by taking hold of the leaf stalk handle to push the point of the shield to the base of the cut. The sliver of wood is not removed if this speedy method of inserting the bud is followed; but if it is found desirable to remove the wood, it is easily done by bending the bark slightly away from the sliver which can then be pulled away with a slight touch. If the bud shield is cut the right size to fit the opening, it is now ready for tying. If too long, however, the protruding end is cut off even with the transverse cut.

To tie the bud properly is important. The turns around the stock need not

overlap, nor do they need to be very close together, but the raffia, string, or rubber strip, or whatever is used, should be drawn taut for each turn. The tie should be started at the base of the cut and continued upwards till the transverse cut is reached, where it is fastened. The rounds should be close to the bud both above and below, but the bud itself should not be covered. If the bud remains alive three weeks, the operation has been a success. After that, if the stock grows in circumference, the tie should be cut to prevent binding, but do not be in a hurry unless growth increases at an excessive rate.

Roses like most other plants grow towards the light. For that reason the bud usually is placed on the side away from the prevailing light. In an open field this would be the north side; but in the home garden might be east, west, north or south. The scion, if united with the stock, will grow equally well no matter which direction the bud faces. It will tend toward an upright growth, however, if it faces away from the light. And by the same token, the bud will grow at a pronounced angle to the stock if it faces the light. If it is found expedient to break this rule, careful pinching can overcome the angular awkward shape.

After checking to make sure the bud is alive, here is nothing more to do, except weeding. The soil should be hilled up over the exposed part of the root if the stock is a seedling, and high enough to cover the bud completely before winter if the stock is a cutting. No hilling is needed in mild climates. A bud may start to grow the same summer it is made and if this happens the stock and scion are both allowed to grow.

When the plant begins new life, in late winter or early the following spring, it is time to cut the top off the understock. This is done with a pair of sharp pruning or lopping shears, the cut being made an inch or so above the seated bud. There may be considerable loss of sap before the wound heels if it is done late, but this in itself is nothing to worry about. The tip of the new bud shoot should be cut off when it is from three to five inches long to force the latent buds on either side of the main one to grow, resulting in a lower, bushier plant.

The bushier plant is mainly for appeal when plants are offered for sale. Actually, the amateur is just as well off letting the plant grow without pinching. It is good precaution to stake and tie the young plant to prevent breakage if the tip is not cut off. The stake should be placed opposite the bud, close to the stock, so close that the two touch each other. The first tie should be below the bud on the stock itself. It should be made quite tight. The next tie should be loose or barely taut, six to eight inches up, and one or two more loose ties should be added as the plant grows. The result of no pinching will be a thoroughly ripe plant which will have a much better chance to survive the first winter if the weather is severe. In the southern states that quality, of course, would not be important. After the first year, there will be little difference between the pinched and unpinched plant.

An interesting variant of budding can be enjoyed by budding first and after the bud has united, rooting the stock afterwards. For this purpose, canes of climbers or species which root early from cuttings, are selected. Again *R. multiflora* is useful. Canes selected should be of the type suitable for cuttings, that is, neither too slim nor too

heavy. The buds are inserted about eight inches apart between nodes, starting near the base of the cane and continuing towards the tip with all buds pointing towards the tip.

As the cane grows and ages, the bark slips with difficulty, or it refuses to slip altogether on the older part. For this reason, the budding should be done gradually with the growing cane if advantage is to be taken of its full length. A procedure described later under the budding of standards may also be used.

At the proper time in fall or winter, when it is found convenient to make the cuttings, the cane is severed from the parent and cut into pieces, each piece with an inserted bud near the top. From there on, treatment is as previously described for hardwood or dormant cuttings.

It is also quite possible to air layer the cane at the same time the buds are inserted. In this case, it might be necessary to place the buds a little farther apart but otherwise, the procedure would be the same. It would, however, be difficult to find a reason for air layering unless it was planned to grow the resulting plants in the greenhouse during the first winter.

Budding may be employed to produce the top as well as the trunk, in the making of a standard or a rose tree. Some of the best understocks for standards, *R. rugosa,* for example, have the bad habit of suckering. This can be overcome by the use of an intermediate stock. To start with, understocks, of a non-suckering type, are planted and in due time budded with the variety, or species, which is to produce the stem or trunk of the standard. When this has grown to the proper size, it in turn is budded at the desired height with the variety which is to form the top. One or more buds are inserted in the usual manner directly in the trunk.

It is at times difficult to get the bark to slip at the desired point. This will be so, if, for one reason or another, budding is delayed until the trunk has lost its youthful attributes. To avoid this difficulty, it is necessary to tie paper or tape over the part selected to receive the buds. The whole area should be covered for a period of two weeks or until the bark is found to slip readily from the wood. The budding of the standard can then be completed.

The buds inserted in a standard do not start into growth, as a rule, as readily as those inserted near the soil line. The top, therefore, should not be completely cut back close to the uppermost bud early in the spring. A piece, which may be as much as ten to twelve inches long, should be left. From this piece of wood, one or more twigs are allowed to grow until the bud gets started. It may be necessary to pinch those twigs once or twice to keep them from taking over. Their sole purpose is to keep the sap flowing in the stem until the buds have grown sufficiently to take over this service. As the bud grows these twigs are removed, leaving the stump for a while longer. It comes in very handy as a support to which the new rose can be tied until it is strong enough to stand alone. At this time, the stump is removed with a clean cut close to the highest placed bud. Any growth along the trunk between the soil line and the top should be removed. A strong stake should be provided to hold the tree in place. The tree will not be strong enough to hold itself upright when the top grows large and heavy.

The ideal understock for tree roses has not been found yet. Several are commonly used, but all have faults.

Here is a challenge for an interested amateur who has the time and inclination to experiment! The researcher should look for a variety, or species, which normally forms heavy canes, is capable of producing good growth and flowers over a period of many years. The understock should be congenial to a number of different varieties of dwarf roses suitable for standards. It should be very hardy and easily propagated. Other desirable qualities will reveal themselves as the experiment progresses.

Grafting

Knowledge of grafting is of value mainly to the amateur who has a greenhouse. Grafting can be done in the open, but apparently the grafted plant does not make as good a rose for outdoor planting as does the budded one. Grafting provides a means of reproducing a variety of which propagating wood could not be obtained at a time when other methods were more feasible. Grafting is also an acceptable method of propagating roses to be grown in pots or in benches for cut flower purposes.

To prepare for grafting, which is generally done during winter, stocks should be potted in the fall and carried in a cool greenhouse until wanted. The pots can be carried in a deep frame, or in a protected place in the open where they can be lifted and carried to the greenhouse when desired. The stocks should not be too large. Just above the rim of the pot where the scion is to be placed, the root, if a seedling stock, or the stem, if a cutting, should be the size of a pencil. Although slightly larger or smaller will do very well.

The scions may be cut from dormant wood, about three inches of stem is sufficient. If the plant to be propagated is already growing in the greenhouse, wood which has just flowered, or wood of the same degree of maturity, will be ideal. The scion is cut with one, two, or more eyes, depending on the distance between the nodes. The leaves, if any, are removed and a clean, slanting cut is made with a sharp knife. The cut is started about an inch and a half above the base of the scion and continued until it emerges at the base on the opposite side. The stock is cut correspondingly and the scion and stock are then fitted together ,tied securely and covered with melted wax or paraffin.

In case stock and scion are of unequal size, it is imperative that the cambium layers of the two be made to correspond on one side as union can take place only where the cambium layers meet. When fitting the two parts together, the cut surface of the scion should extend a small fraction of an inch beyond the top of the stock to facilitate a smooth union. Also, it is important that the two cuts be on an even plane because the slightest curve will mean a poor fit, and failure can be expected.

Grafting can also be done on root pieces. Rose species which do not sucker should be selecterd to provide the roots. *R. odorata* and *R. multiflora* are the species commonly used for the work. Pieces of root can be dug during fall or winter and stored in moist sand or peat moss as cool as possible until needed. The roots may be cut into pieces about three to four inches long before grafting, or for easier handling, may be cut off at the proper length after the scion is attached. The caliper of the root pieces should be comparable to that of the scions.

The scion and root should be cut,

fitted and tied together as already described. The scion, including that part of the root to which it is now fastened, is dipped in melted wax or paraffin, but the part of the root below the union is left unwaxed. Care should be exercised so that the melted wax does not get too hot as it may cause scalding. Potting in two inch rose pots should then be done in such a manner that a scion, including the part of the root where the graft is seated, remains above the soil level.

A temperature from fifty to sixty degrees is advisable depending on the weather and season, and a light shade may be desirable for a week or two. Growth should begin in two to four weeks and be quite rapid. When growth is well advanced, the tie is cut along the back of the stock to allow for natural expansion.

While such grafted plants can be planted outdoors in the late spring, the method is one primarily for greenhouse growing, or as a temporary expedient to carry on a species or variety which otherwise would be lost.

Labeling has been referred to only once or twice, but it goes without saying that the amateur who takes pride in his plants, will be careful with labels as well as permanent records during all his operations.

Propagation Of House Plants

Clark L. Thayer[1]

The subject of plant propagation, that is, increasing the number of a given kind of plant, is always—interesting to anyone growing plants. There is great satisfaction in starting the plants which are to be grown on especially in the home, or which are to be given to friends, perhaps in exchange for varieties which they have propagated. There are many methods which may be used, the choice of method usually depending on the particular kind of plant which is to be increased.

Seed propagation first comes to mind since it is the method most commonly found in nature. From the point of view of the average grower of house plants, however, this method frequently has one objection in particular—the length of time required to grow a given plant to maturity or to its flowering stage. Not all beginners would have the patience to wait fifteen to eighteen months after the seed is sown for a cyclamen plant to come into flower. On the other hand, many amateurs have been successful in raising such plants as the gloxinia and the Saintpaulia from seeds. Palms, which are sometimes used in the home if there is sufficient space, can be propagated only from seed, with the greater number of the species. Within recent years a small palm has been introduced by the trade which appears to be a satisfactory species for house plant use because of its small size. It is being used in dish gardens, or planters, as they are now commonly called, and is also sold as an individual plant. Botanically it is known as *Chamaedorea elegans* (also

[1]University of Massachusetts, Amherst, Massachusetts.

Neanthe bella). It should be remembered, however, that eventually it will become a plant of considerable size.

The simplest method of propagation of house plants is by division which may be used for those plants developing a more or less dense crown. Common examples would be such plants as the Maidenhair Fern, all ferns of the Boston type and related varieties and the African-violet. The plant is removed from the pot and, by breaking apart or cutting with a heavy knife, is divided into sections. Each of these divisions should contain portions of the parent plant which would enable it to perform the functions of a complete plant.

Many house plants, such as coleus, Pelargonium, fuchsia, and certain begonias are propagated by softwood stem cuttings, commonly called "slips" by home gardeners. These cuttings should be made from terminal or tip growths which are neither tough and woody nor soft and succulent. The stem should be somewhat brittle, breaking cleanly when bent between the fingers. With a sharp knife, a smooth, slanting cut is made just under a node, or at a point between two nodes to obtain a desirable length of cutting, usually not exceeding three or four inches. The lower leaves on the cutting should be removed to facilitate placing the cutting in the propagating medium, to reduce the amount of water lost from the leaf by transpiration, and to economize on space.

In my class work with women students in Amateur Floriculture the Forsyth pot has proved a satisfactory method of rooting such cuttings. One piece of broken flower pot is placed with the curved side up over the drainage hole in a standard six inch pot. Drainage material, such as broken pots, coarse screenings from coke or coal ashes, pebbles or crushed stone, is then added until the pot is about half full. A layer of sphagnum moss, a piece of glass fibre cloth, or a piece of burlap is placed over this drainage material to prevent the sand from seeping down into the drainage. The hole in a three inch standard pot is plugged from the outside with a cork, modelling clay, or plaster of Paris. The small pot is then placed in the larger pot so that their tops are about level. Clean, sharp sand is then placed in the space between the two pots, watered thoroughly and firmed. The cuttings are placed in the sand, firmed, and watered to help settle the sand around the cuttings. The small pot is kept filled with water, which, seeping through the porous pot, keeps the sand uniformly moist. Kept in a semi-shady location the cuttings, should root readily, the length of time depending on the particular plant. When well rooted, as indicated by the resistance offered to a slight pull, they should be removed and potted individually in two and one-half or three inch pots.

Root-inducing hormones may be used on such cuttings, if desirable. There is no point in using a hormone on cuttings of such plants as coleus and ageratum, which root very easily. For softwood cuttings, a weak concentration is desirable. Directions for using powders should be followed as given on the container.

Two new techniques in rooting softwood or hardwood were developed recently by Lewis F. Lipp, Plant Propagator at the Arnold Arboretum. These can be adopted to rooting of house plant cuttings. The procedures recommended are as follows: 1) Dip the basal ends of the cuttings in a root-inducing powder; insert the cuttings in

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Figure 29. African-violet leaf cuttings showing development of new plants at bases of leaves.

a pot or flat containing a mixture of sand and peat moss; cover the container and cuttings with a polythylene plastic, making certain that this miniature tent fits tightly around the container. Humidity is retained with the loss of very little water by evaporation and transpiration, and frequent watering is unnecessary. 2) A strip of polyethylene plastic about eight inches wide and two or three feet long is placed on a table; a thin layer of moist sphagnum moss is laid on the longer upper half of the strip; the cuttings, which may have been dusted at the base with a root-inducing powder, are then laid on the moss leaving the foliage exposed; the other half of the strip is folded over the cuttings and the moss and the strip is then rolled up and tied firmly.

On the basis of our experience, it is desirable to cover the exposed tops with a second piece of plastic or to place the bundle under a glass jar to maintain humidity and reduce transpiration and evaporation. It should not be necessary to add water to the moss during the time required for rooting.

Many plants which have the ability to develop adventitious buds and roots on leaf stems, entire leaves, or sections of leaves, may be propagated from such parts of the plants. The most common example of the first type is the popular African-violet. (This plant, first described about sixty years ago, has now apparently become our most popular house plant.) A complete, mature leaf is removed from the parent plant by cutting it near the crown to avoid leaving a stub. The stem may then be reduced in length or used as it is taken from the plant. (There is a difference of opinion as to whether a long or short

stem gives quicker or better results.) The leaf stem cutting may then be rooted in various media—water, sand, peat moss and sand, sphagnum moss, or vermiculite. Adventitious buds and roots develop from the base of the petiole. (Figure 29). After the new plantlet has formed, the parent leaf may be removed and reused to produce still another plant.

A most interesting plant for the amateur from the viewpoint of curious propagation is *Bryophyllum calycinum,* also known as *Kalanchoe pinnata,* commonly called the life plant or air plant. A leaf of this plant, received in a letter from Hawaii, was pinned on the drapes of a window with a southern exposure and developed plantlets at the serrations on the margin of the leaf. It is generally propagated, however, in a rooting medium. (Figure 30).

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Figure 30. Leaf cutting of Bryophyllum calycinum showing newly developed plantlets at the serrations of the leaf margin.

Cyperus alternifolius, the Umbrella Plant or Umbrella Flat-Sedge, is not as commonly grown as a house plant as it should be. It has interesting foliage and produces an excellent example of informal, yet symmetrical balance if allowed to grow in its natural manner. It is propagated by a type of stem cutting—not as a leaf cutting as it is sometimes thought to be. One method is to cut a stem from the plant, then remove all the stem up to the point from which the leaves arise and place the remaining portion in an inverted position in a shallow container of water. Plantlets will arise from the axils of the leaves which may then be removed and potted individually or as a group as they formed. Another method is to retain about one inch of the stem as an anchor, cutting the leaves back to about two or three inches to reduce transpiration and tying them together so that they occupy less space in the propagating medium. The cutting is then placed in the sand in the normal manner or other medium so that the axils of the leaves are below the surface of the medium. After plantlets arise they may preferably be separated or the entire crown may be planted. (Figure 31). Better results are obtained if the cutting is made before the flowers have developed.

Two of the old reliables among house plants are *Sansevieria trifasciata,* bowstring hemp, snake plant, and its variety *laurenti,* the form with the yellow margin on the leaf. While, in the opinion of many persons, they are not beautiful, they do have the ability to withstand extremely adverse conditions, such as low temperatures, low humidity, and poor light. The true

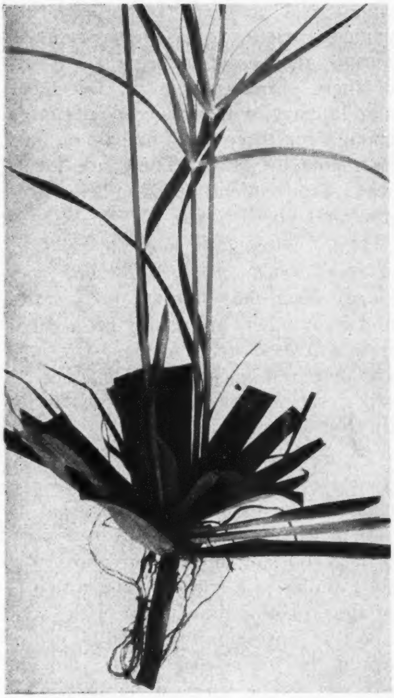

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Figure 31. Plantlets arising from leaf cutting of Cyperus alternifolius, rooted in sand.

species may be propagated by entire leaf or sectional leaf cuttings. (Figure 32). If the leaf is cut in sections, it is necessary to observe polarity when placing the cuttings in the propagating medium. Polarity, in this case, is defined as the tendency of a cutting to produce roots from that part of the cutting which was nearest the base of the parent plant. This can be assured by a simple practice of making a slanting cut at the base with a horizontal cut at the top. Adventitious roots and buds arise from the base after a period of several weeks at which time the cutting and plantlet should be potted. In the case of the variety *laurenti,* however, it is necessary to propagate plants by division since sectional leaf cuttings will revert to the species. (Figure 33).

The genus *Begonia* is of great interest to growers of house plants, not only because it provides so many species and varieties satisfactory for indoor use, but because it offers several methods of propagation. Seed, stem cutting, leaf-petiole cutting, entire, and sectional leaf cutting, tuber and tuber division are methods which may be used with the various types.

From the amateur point of view, tubers are undoubtedly the least important since the home flower grower will usually purchase the tubers—not attempting to produce them from seed. Large tubers can be cut into sections when they are dormant or at least when the eyes or buds are visible. The tuber is cut into sections so that there is at least one bud on each piece.

Figure 32. Rooted, sectional leaf cuttings of Sansevieria trifasciata.

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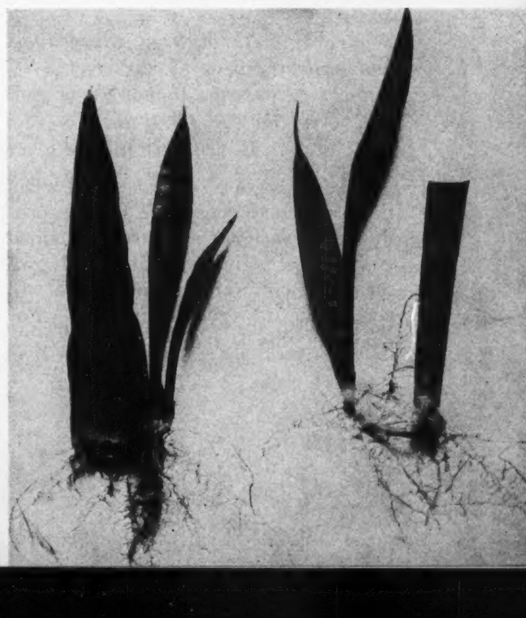

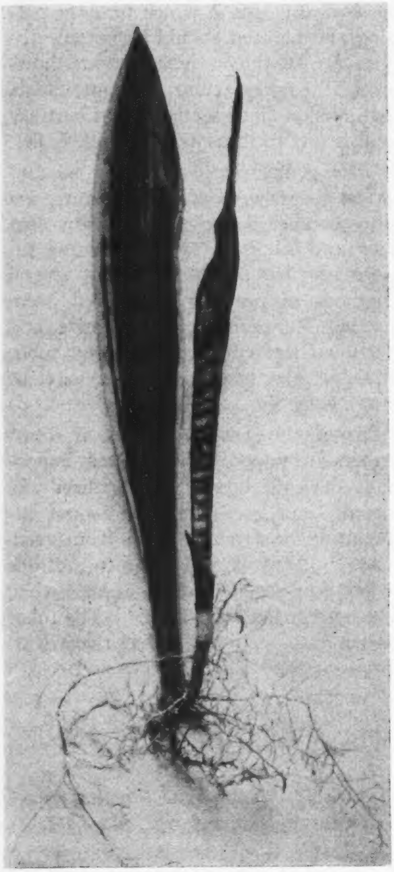

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Figure 33. Shoot from adventitious bud on leaf cutting of Sansevieria trifasciata v. laurentii showing reversion to true species.

Seed of begonias may be used when it is desired to reproduce species, produce new varieties with seeds obtained from cross pollination, and to reproduce horticultural varieties which will come true to type from seed. For example, this last method is used by commercial growers in propagating named varieties of *Begonia semperflorens,* the perpetual begonia. Seeds of these varieties sown in December and January, will produce plants large enough for three and one-half or four inch pots by May. These are forms which are frequently used in beds, window and porch boxes.

Many species of begonia such as *semperflorens, argenteo-guttata, coccinea, haageana, foliosa, fuchsioides,* and many others are readily propagated from softwood stem cuttings. Cuttings are prepared in the same manner as was described for inserting cuttings in the Forsyth pot.

Entire leaf cuttings are frequently used for the begonia which have the rhizomatous habit of growth, that is a stem which usually grows in a more or less horizontal position above the soil, similar to a true rhizome which is produced below the surface of the soil. Species representative of this group would be *ricinifolia, feasti, bunchi,* and *rex.* The simplest method is to remove a leaf from the plant, cutting off the petiole at a point near the union of blade and petiole. The leaf is then laid on the propagating medium, usually sphagnum moss or sand, in a shallow container. If necessary the leaf may be pegged down to keep it in close contact with the medium. Occasionally, the main veins in the leaf are cut to produce additional plantlets. Adventitious buds and roots should develop at or near the point of union of blade and leaf and also from the scored veins. (Figure 34). It is essential that the medium should be kept moist with the flat or other container in a shady or semi-shady window.

Many species of begonia in this rhizomatous group may also be propagated by sectional leaf cuttings. The

Figure 34. Adventitious buds and shoots from a complete leaf cutting of Begonia showing development of new plants along the main veins which were cut when leaf was placed in the medium.

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petiole is removed as described in the previous paragraph; the leaf is then cut into sections so that there is at least one main vein and a small section of the petiole on each piece. About one-third of the leaf blade may be removed to lessen the amount of transspiration. The prepared cuttings are then placed vertically in the propagating medium, with the base of the cutting half an inche to one inch below the surface. This method is usually preferred by commercial growers since more cuttings may be placed in a given amount of bench space.

The varieties of the begonia which are so commonly seen in retail flower stores at the Christmas season, such as Melior, Marjorie Gibbs and Lady Mac, are propagated from leaf-petiole cuttings. A leaf with the entire petiole is removed from the parent plant, the petiole inserted in sand to a depth of about one inch, with the blade of the leaf not resting on the sand. A crown of scale-like growth develops at the base of the petiole from which will arise the main stem of the plant. Bottom heat is essential for the rooting of such cuttings. Doubtless many amateurs prefer to purchase plants in full bloom since approximately one year is required to bring such a plant to its full size and full bloom. Frequently, the commercial grower removes a few leaves for propagation purposes from each plant before it is sold to the retailer and from such leaves produces his stock plants for the next Christmas.

Peperomia sandersi argyreia, frequently called the watermelon begonia, although in no way related to the begonia, is an attractive plant for home use because of its silvery striped foliage. It requires a high temperature and high humidity. The most common method of propagation for the amateur is a leaf-petiole cutting. Roots and buds develop from the base of the petiole as well as from the point of union of blade and petiole if the leaf is placed deeply enough in the medium. In our opinion *Peperomia magnoliaefolia,* also known as *P. obtusifolia,* is better adapted to general home use since its tough, leathery, dark green foliage gives better results under adverse conditions, such as low or high temperatures and low humidity. This species and its variety, *variegata,* are readily propagated from leaf-petiole cuttings or terminal, softwood stem cuttings. After the plantlets have formed the original leaf may be removed and used again for propagation or it may be kept on the new plant.

Air layerage is a method which makes it possible for the home flower grower to get rid of long-legged plant by rooting the top of the plant and discarding the remainder when the top has formed roots and has been severed from the long stem. This method is also known as Chinese and pot layerage, although it is not necessary to use pots in the process. The method should give one hundred per cent rooting since the top is receiving nutrients and water from the soil until the top portion is severed from the stem. The amateur may have a plant of *Ficus elastica, Codiaeum variegatum,* Dieffenbachia, or *Dracaena deremensis warnecki,* which has become unsightly because of the loss of leaves from the lower part of the stem. With a sharp knife an upward cut is made in the stem at the point where it is desired to have roots form. The cut should preferable go through at least one node or joint and should extend about half way through the stem. If the plant has a milky juice, as in Fiscus, it is desirable to insert something in the cut to keep it open—a bit of wood, for example. The cut is then wrapped firmly in a handful or more of damp sphagnum moss which must be kept moist during the rooting process; the moss being tied in place with light copper wire or a strong light twine. Green florists' thread is very satisfactory for this purpose since it does not decay quickly. The ball of moss may be wrapped in cellophane or a plastic material to improve appearances and to prevent rapid evaporation of water from the moss. Because of the weight of the ball of moss it may be desirable to stake the layered plant, especially if it has a slender stem such as are present in Codiaeums. A ring of bark is sometimes removed (girdling) at the point where it is desired to have roots develop in preference to making the upward cut. Dusting the cut surface, in either method, with a weak root-inducing substance may assist in speeding up the rate of root development. It may require several weeks for roots to form. When they appear through the moss, the stem is cut off below the moss and the newly rooted top is potted, either with or without the moss.

During recent years much experimental work has been done along the lines of producing equipment for house plant propagation purposes, making use of artificial light as a source of heat and light. Many amateurs have been successful in rooting cuttings of various types in their cellars with the use of such equipment. Possibly the African-violet has been used to the greatest extent in such propagation. One of the most effective of such so-called plant propagators is that which was developed at the Glenn Dale station of the United States Department of Agriculture, discussed in detail in other papers in this issue of the Magazine. While many house plant growers might consider it too expensive for home use, when only a few plants are to be propagated, nevertheless, there are others who would consider it to be an indispensible piece of equipment.

Books On Plant Propagation

While there are several text books on the art of propagating plants, those discussed here are thought to be typical of the range and manner of presentation of most such publications.

Propagation of Trees, Shrubs, and Conifers. Wilfred G. Sheat. Macmillan and Co., Ltd. London. 1948. 479 pages, illustrated. This is the most useful of the recent manuals on the propagation of woody ornamental plants. The reason being that only some twenty-five pages are devoted to general discussion and the remainder of the book describes the propagation methods for individual species. Here the reader will find notes on almost any woody species with detailed instructions on methods—the latter being arranged in order of importance. If there is a failing in this text, it is due to a lack of respect for modern propagation adjuncts, for example, growth regulators are hurriedly skipped over in the general discussion. This has been coped with, however, by skill and patience of such a quality that most plants can be propagated successfully following the recommendations of this well-versed propagator.

Propagation of Plants. M. G. Kains and L. M. McQuesten. Orange Judd Publishing Co., Inc. New York. 1946. 555 pages, illustrated. A number of schools teaching courses in plant propagation use this text and it has been prepared with considerable respect for the scientific approach to the subject. Since all phases of propagation must be covered in this type of book, ornamentals receive only a share of the effort. As a consequence, one will not find it a ready reference to propagation requirements of different ornamental species but rather a thorough treatise on methods, illustrated by a wide range of examples. Due to the extent to which the authors have accumulated data from propagation research, the text may be considered as a thorough and authoritative.

Plant Propagation. Alfred C. Hottes. A. T. DeLaMare Co., Inc. New York. 1937. 228 pages, illustrated. The beginning amateur will find this a ready source of information on the simple means of propagating plants. Because of this, it may not satisfy the requirements of the individual interested in succeeding with rare and difficult plants. At the end, one will find a several page listing of plants with their propagation methods in brief outline form.

Propagation of Ornamental Plants. John V. Watkins. Bull. 150 Agri. Extension Service. University of Florida, Gainesville, Florida. 1952. The difference in the range of ornamentals grown in various parts of the United States requires that there be local discussions on the subject of plant propagation. This particular bulletin serves the subtropical gardner and is suitable for conservatory plants. The scope is limited by space but the details of propagation are all covered and illustrated. Recent methods such as the use of mist and plastics are described.

The Propagation Of Some Trees And Shrubs By Cuttings. William L. Doran. Mass. Agri. Experiment Station Bull. 382. University of Mass., Amherst, Mass. 1941. This bulletin has been one of the most popular for information on rooting cuttings of a wide range of difficult plants. Subject matter discusses time of taking cuttings, media and results with individual species. Growth regulators figure largely in the discussion but there is no prejudice in their favor where rooting was noted to be as successful without treatment.

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